THE

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No. XII.—DECEMBER, 1919.

EDITORIAL NOTES.

ALTHOUGH the situation with regard to the future of the GEOLOGICAL MAGAZINE is still somewhat critical, it is satisfactory to be able to state that the worst anticipations have not been realized. At one time it was feared that the present number would have to be the last, but we are glad to be able to announce that it is proposed to carry on, for the present at any rate, in the hope of better times to come. But it cannot be too strongly emphasized that the future rests with our subscribers. Many promises of active support have already been secured, and the outlook is more promising than it was a few months ago. While still maintaining all the old features and the general traditions of the Magazine, every attempt will be made to move with the times and to give due weight to new developments. Geology has now become a science of the widest practical importance in all parts of the world: some of the apparently most abstruse and theoretical investigations of late years were primarily undertaken to subserve economic purposes and have proved to yield results of the highest value and importance in technical practice of all kinds. Unfortunately this fact is little realized in this country, and it is the duty of all modern geologists to keep in touch with such new developments wherever they are to be found, whether in America, Scandinavia, or Germany. Geology is necessarily an international science; it will be our desire and hope so far as in us lies to assist in making known its latest developments, of whatever nature they may be. Above all we shall endeavour to avoid that insidious blight of parochialism and narrowness of interest which has at times threatened to manifest itself in British geology, especially in isolated provincial circles, and to accommodate ourselves to the widening spirit of the times in which we live. Although our circulation is not large, it is wide: we have many contributors beyond the seas, and one of the pleasantest features of the Editorship is the opportunity that it gives for friendly personal communications with these distant workers on subjects connected with geology in all its branches.

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AT the Anniversary Meeting of the Mineralogical Society, held on November 4, the following Officers and Members of Council were elected: President, Sir William P. Beale, Bart., K.C.; Vice-Presidents, Professor H. L. Bowman, Mr. A. Hutchinson; Treasurer, Dr. J. W. Evans, F.R.S.; General Secretary, Dr. G. T. Prior, F.R.S.; Foreign Secretary, Professor W. W. Watts, F.R.S.; Editor

of the Journal, Mr. L. J. Spencer; Ordinary Members of Council, Mr. H. F. Collins, Mr. J. P. De Castro, Professor H. Hilton, Mr. Arthur Russell, Dr. A. Holmes, Miss M. W. Porter, Mr. R. H. Rastall, Sir J. J. H. Teall, F.R.S., Mr. A. F. Hallimond, Dr. F. H. Hatch, Mr. J. A. Howe, and Mr. W. Campbell Smith, M.C.

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The Committee appointed by the Board of Trade to consider and report on non-ferrous mining in the United Kingdom has apparently lost no time in getting to work. It was decided to deal with the tin-mining industry first, and a good deal of expert evidence has already been taken. The general opinion of mine-managers from Cornwall, with one or two notable exceptions, seems to be in favour of the policy of amalgamation and concerted development with a view to the reduction of costs and increased production. Several witnesses expressed the view that some form of Government subsidy was highly desirable, and the advance of £1,000,000 to the Anglo-Persian Oil Company was quoted as a precedent. Nevertheless, the idea of nationalization did not seem to receive much sympathy. The Cornish tin and wolfram mining industry rendered signal services to the country during the War, and this should make the Government and the nation all the more inclined to afford assistance towards the development of this important branch of our mineral resources. The geological evidence appears to be all in favour of the existence of rich deposits of tin at deep levels, both in hitherto unworked areas and in districts where many shallow mines have been abandoned: it is much to be wished that opportunity should be given to test the validity of the conclusions largely founded on scientific reasoning.

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The Imperial Mineral Resources Bureau has issued a kind of interim Progress Report showing the steps that have already been taken. The Charter has now been received and numerous committees are already formed, consisting of experts in each branch together with representatives of technical and scientific societies dealing with that special subject. It is satisfactory to find that arrangements have been made with the Imperial Institute by which duplication and overlapping will be avoided and a harmonious co-operation assured. Similarly the Home Office has handed over to the Bureau certain duties hitherto performed by it in connexion with the Annual General Report of the Chief Inspector of Mines. The compilation of part iv of that Report, British Empire and Foreign, will in future be undertaken by the Bureau. Two lists are appended to the report showing the countries with which the Bureau is in active correspondence, either directly or through diplomatic and consular offices. The present writer is not aware of the geographical position of the state of Latvia, nor is it clear why information as to the Dutch East and West Indies and Guiana should be obtained from the Colonial Office, Copenhagen, or as to Nicaragua from the Central Statistical Office at Christiania.

ORIGINAL ARTICLES.

I.—*Bunaia Woodwardi*, a New Merostome from the Silurian Waterlimes of New York.

By John M. Clarke, LL.D., For. Corr. Geol. Soc. Lond., Director of the New York State Museum, Albany, N.Y., U.S.A.

(PLATE XIV.)

Prefatory remark by author.—Dr. Henry Woodward has asked me to prepare for the Geological Magazine a brief sketch of this new fossil. It seems to me most appropriate that the Magazine, the sturdy child of this eminent and venerable palæontologist, and the expositor of so many of his own observations on Palæozoic Crustacea, should carry the first printed account of this discovery, which I have taken pleasure in dedicating to Dr. Woodward, my colleague and friend of many years.

THE hydraulic limestone series which cap the Silurian rocks of the New York sections, and are commonly embraced under the name "Salina Group", are probably the richest known depository of remains of the Merostome Crustacea. During the past fifteen years we have been engaged upon the study of this fauna, and the results at which we arrived in our memoir on the Eurypterida of New York [1] could not have been safely attained without the previous labours of Dr. Woodward and the late Professor Rupert Jones, of Huxley, and Hugh Miller for the British species; of Friedrich Schmidt, Nieszkowski, and Holm for the species of the Baltic basin.

We now recognize in the Salina basin of New York over sixty species of the Eurypterida (*Eurypterus*, *Pterygotus*, *Dolichopterus*, *Stylonurus*, etc.), and to this large number are to be added two species of the rare genus *Pseudoniscus*, which had heretofore been found only in the Baltic beds. In the North European development of this shallow-water coastal bay fauna there are three genera of Merostomes which the New York deposits have never revealed: *Hemiaspis* and *Neolimulus*, from the Scottish Silurian, and *Bunodes* from the Island of Oesel. What we are now designating by the name *Bunaia* may be regarded as an alternative expression of *Bunodes*, which according to the descriptions by Eichwald, Schmidt, Nieszkowski, and more recently by Patten (*The Vertebrates and their Kin*) is a creature 2–3 inches long, with short semicircular head, a broad mesosoma of six segments, followed by three narrow segments of the post-abdomen and a long single telson-spine. The head is marked by five curved radial furrows diverging on each side from the central subtriangular glabellar elevation; and these divide the surface into corresponding radial ridges. Dr. Patten has called attention to the retention of this primitive structure in the *Limulus* embryo, a fact which certainly seems to bespeak the direct descent of the latter from this ancient primitive merostome.

The New York fossil is like *Bunodes* in these cephalic structures. Though of very much smaller size, the carapace shows on the upper surface the same arrangement of parts, and on the underside this

[1] Clarke & Ruedemann, Mem. 14, pts. 1, 2, N.Y. State Museum, 1912.

pentameral division is clearly accompanied by remains of the five pairs of legs, the mouth orifice, and, as it seems, the chelate first legs folded down close alongside the mouth.

We illustrate here in connexion with these features a head of *Bunodes lunula*, the Oesel species, showing a similar arrangement of the five pairs of legs and, in addition, what appear to be the lateral thickenings of the glabellar ridges. This is a specimen from which the very thin epidermal film has been removed. Further, the head-shield of *Bunaia* displays more than that of *Bunodes* in its thickened margins and extended cheek-spines. Patten believed that antennæ were present in *Bunodes*, and so restored it, but we find no evidence of these structures in *Bunaia*.

In our specimens the chief difference of *Bunaia* from *Bunodes* is in the structure of the abdomen. In the latter there are six broad segments followed behind by three narrow ones. In *Bunaia* this structure appears to be somewhat different. The cephalon or head-shield is followed behind by narrow segments of which seven or eight can be counted, with possibly one missing. These seem to be of somewhat unequal length and to be longitudinally ridged, but without lateral flanges. Our knowledge of this structure is restricted to a single example and is subject to modification. In one of the three specimens there is a broad detached smooth spine lying alongside the head, which may have been the telson, though apparently pretty large for the species.

The measurements are as follows: width of carapace, 8 mm.; estimated total length of animal, inclusive of telson, 23 mm.

The specimens of *Bunaia Woodwardi* are from the Bertie Waterlime of the Salina Group at East Buffalo, N.Y.

EXPLANATION OF PLATE XIV.

BUNAIA WOODWARDI, sp. nov., J. M. Clarke.

FIG. 1.—A weathered exterior of a head-shield showing the triangular central area or "glabella" and the five pairs of lateral lobes crenulating the surface and corresponding to the legs beneath. × 8.

FIG. 2.—The interior of a head-shield with five pairs of radial appendages and evidently a sixth pair at the central mouth. The light-coloured lines on the right-hand radial areas are elevated linear ridges which appear to be parts of the appendages themselves, and it is thought that the broad dark areas may include both legs and gills. × 8.

FIG. 3.—A crushed and defaced head-shield with a postabdomen of ridged segments. × 8.

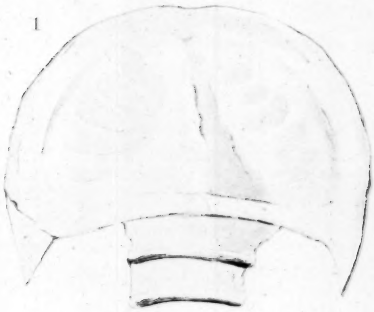
FIG. 4.—A telson spine which lies close to the specimen Fig. 1 and, it is thought, may belong to this species. × 8.

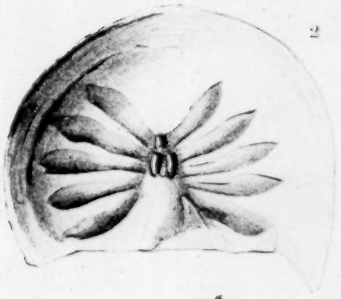
All the foregoing are from the Bertie Waterlime (Silurian) at the East Buffalo, N.Y., quarries.

BUNODES LUNULA, Eichwald.[1]

FIG. 5.—An exfoliated carapace from the Silurian of the Island of Oesel, showing the broad dark bands left by the six pairs of cephalic appendages and also the central divergent ridges which seem to be the interior projections of the ridges of the "glabella". × 3.

[1] Dr. d'Eichwald, Archiv für die Naturk. Liv.-Ehst.- und Kurlands, erste Serie, vol. ii, pl. ii, figs. 12–13, 15, pp. 378–82, Dorpat, 1859, 8vo.





J. M. Clarke, del. Dale, imp.

FIGS. 1-4. BUNAIA WOODWARDI, *sp. nov.*, J. M. CLARKE.
FIG. 5. BUNODES LUNULA, EICHWALD, 1859.

II.—The Geology of the Isle of Purbeck.

Abstract of a lecture delivered to Section C, British Association, Bournemouth, by Sir Aubrey Strahan, K.B.E., Sc.D., F.R.S.

THE "Isle" of Purbeck includes part of a heathy tract underlain by the Tertiary beds of the Hampshire Basin, a central ridge formed by the Chalk which rises abruptly from beneath those beds, and, in its southern part, a hilly region underlain by Wealden, Purbeck, Portland, and Kimmeridge strata, and terminated by bold cliffs. Each formation gives rise to characteristic features in the landscape, the Portland Stone especially forming a dominant escarpment and vertical sea-cliffs.

The emergence of the Chalk and underlying formations from beneath the Tertiary beds is due to an extremely sharp fold accompanied by overthrusting. The age of the movement is proved in the Isle of Wight to have been post-Oligocene, inasmuch as the Oligocene strata are there involved in it. On the other hand it was accomplished, and the uplifted strata were exposed to prolonged denudation, in pre-Pliocene times. The sagging of the strata which led to the formation of the Hampshire and London Basins and the arching-up of the intervening Wealden anticline are attributable to the same period and to the same earth-movement. So energetic a movement, coming into activity at so late a geological age, had a profound influence upon the physical geography of the south-east of England. The principal rivers, the Thames and Frome, each followed a syncline eastwards. On either side they received tributaries which rose upon the anticlines. The anticlines, however, have suffered severe denudation and no longer maintain their dominance of elevation, but the rivers have kept their courses, and now cross in narrow defiles the Chalk ridges which formed the foundations of the once continuous Chalk arch. Admirable examples of such defiles are shown at Corfe Castle.

The curve of the strata in the Isle of Purbeck may be compared to the figure 2. The lower limb of the 2 represents the horizontal beds of the Hampshire Basin, the middle limb shows the strata in a vertical or inverted position, while the upper limb illustrates the gentle curve by which they regain a more normal position. The strain, however, was too great to be relieved by folding alone, and overthrusting on a considerable scale came into play. The cliff-section of Ballard Down shows curving strata which belonged to the lower limb of the 2 resting upon the edges of vertical strata which belonged to the middle limb, a sharply defined slide-plane (the Isle of Purbeck fault) separating the two. Westwards from Lulworth Cove innumerable subsidiary thrust-planes can be detected in the Chalk, and less easily in the Wealden and Purbeck beds. Everywhere along the line of the Isle of Purbeck fault the Chalk is greatly hardened, while the flints are broken, pulverized, and even drawn out into streaks of flint powder. The Isle of Purbeck fault dies out under Weymouth Bay, but is replaced a mile or two to the north by the parallel and still more energetic Ridgeway overthrust.

As regards the regions which it was proposed to visit, in the

neighbourhood of Swanage the whole sequence from the base of Upper Chalk to the Portland Stone is open to examination, but time would not admit of more than a brief inspection of the Purbeck and Portland cliff-sections. The Upper Purbeck with Paludina Limestones or "Marble-beds" and Unio beds form Peveril Point, and the Middle and Lower Purbeck beds are shown more or less continuously in Durlston Bay, a band composed of shells of *Ostrea distorta* (the "Cinder Bed") forming an easily recognized horizon. About 30 feet below it lies the Mammal bed, a thin earthy layer which has yielded the remains of several genera of marsupials. Below this again are the Lower Purbeck limestones and marls, some with gypsum, casts of crystals of rock-salt and insect remains, others yielding a brackish-water estuarine fauna. A double fault, with a downthrow of 100 feet to the south near the zigzag path, throws the Cinder Bed from the top of the cliff to below the beach. The junction with the Portland Stone is not well shown in Durlston Bay.

The cliffs near Kimmeridge give a continuous section from the lowest Purbeck (on the top of St. Albans Head) to a low horizon in the Kimmeridge Clay, more than 1,000 feet of strata in all. From the head westwards they show a descending section in gently inclined strata, and at rather more than 500 feet below the top of the Kimmeridge Clay the "Kimmeridge Coal" or "Brownstone" emerges from below the beach. This highly bituminous layer is about 2 ft. 10 in. thick and has been worked in the neighbourhood from time immemorial, firstly for the manufacture of ornaments or utensils, latterly as a fuel, and as a source of oil. During the War it attracted much attention as a possible source of oil and other products. Alum was also manufactured here. In Hobarrow Bay the main anticlinal axis is reached, and thence westwards the same strata are crossed in ascending order, until the beetling crag formed by the Portland Stone comes down to the beach and stops further progress.

Lulworth Cove illustrates the effect of attacks by the surf upon nearly vertical strata varying in their power of resistance. The Portland Stone has formed a natural breakwater, which, however, has been breached in places. Stair Hole shows the first effects of a breach; the waves have worn holes through the stone and are swilling the debris, the soft Upper Purbeck and Wealden strata, through them. In Lulworth Cove the breakwater has been completely broken through and a beautifully symmetrical natural harbour formed in the outcrops of the Purbeck, Wealden, and Gault formations. Everywhere the sea suffers a prolonged check on reaching the Chalk.

The coast east of Lulworth Cove shows all the formations below the Chalk except the Lower Greensand, but much attenuated as compared with Swanage. Here an unconformity below the Gault, which becomes most pronounced at White Nothe a few miles westwards, becomes manifest for the first time. The absence of Lower Greensand may be due in part to overstep by the Gault, and some of the uppermost Wealden beds may be absent for the same reason. The section at White Nothe shows the Gault resting on steeply

upturned Wealden, Purbeck, and Kimmeridge strata, and proves that there had been produced in pre-Gault times a set of flexures wholly independent of those of post-Oligocene age, though parallel to them. These earlier flexures are ignored by the rivers.

Mupe Bay, east of Lulworth Cove, affords a clear view of the passage of the Purbeck beds up into the Wealden, and of the abrupt but conformable junction of the Lower Purbeck and Portland Stone. Half a mile east of Lulworth Cove a ledge of the cliff provides an unrivalled opportunity of examining the lower part of the Purbeck beds, including the junction with the Portland Stone, the thin layer of carbonaceous gravelly soil known as the dirt-bed, numerous stumps and prostrate trunks of coniferous trees silicified and enclosed in calcareous tufa, and the brecciated limestones associated with tufa, known as the "broken beds". Here the incoming of bands of tufa, among the sedimentary limestones, and the close association of such incoming with brecciation of the limestones, can be studied in detail. Westward from Lulworth Cove the cliffs illustrate the intense compression and supplementary overthrusting which all the formations have undergone in the neighbourhood of the Isle of Purbeck fault.

III.—The Origin of Cretaceous Flint.

By W. Alfred Richardson, M.Sc., B.Sc. (Eng.), F.G.S., A.M.I.Min.E.

1. Introduction.

IT will be recalled that to the list of theories relating to the origin of flint Liesegang[1] has added another, namely, that the flint is due to the rhythmic precipitation of a silica solution diffusing through the Chalk. Cole[2] in an admirable essay has made this view accessible to English readers, and at the same time somewhat expanded the original suggestion. Yet little by way of evidence is offered beyond a certain plausibility in the idea, and its undoubted competence to explain better than any other hypothesis yet suggested the remarkably regular recurrence of flint lines. When reading over the chief Cretaceous literature with this problem in mind, there seemed to me to be a not inconsiderable body of fact lending support to this view. Accordingly the object of this paper is to examine existing data in the light of Liesegang's suggestion in order to see whether or not it may be regarded as a reasonable working hypothesis.

There are three outstanding questions connected with flint-origin which still await decisive answer. They are, namely:—

1. The age of formation relative to the Chalk.
2. The source of the silica.
3. The cause of the regular recurrence of flint bands.

This paper is only indirectly concerned with the first of these questions, and I shall, therefore, only summarize the position with regard to relative age and pass directly to a discussion of the remaining questions.

[1] R. Liesegang, *Geologische Diffusionen*, Dresden and Leipzig, 1913, p. 126.
[2] G. A. J. Cole, Geol. Mag., 1917, pp. 64–8.

2. The Relative Age of Formation.

The flint, relative to the Chalk, may have been formed either—

(*a*) *Contemporaneously* by original deposition, either organically as advocated by Bulman,[1] or chemically as held by Tarr.[2]

(*b*) *Penecontemporaneously* by segregation of silica disseminated in the ooze of the Cretaceous sea, as Van Tuyl[3] seems to think.

(*c*) *At the time of uplift* by diffusion, precipitation, and replacement, as advocated by Cole and Liesegang.

(*d*) *Subsequent to uplift and complete consolidation.* With regard to (*d*) there is no direct evidence. On the other hand there is something to be said for each of the other relative times. Setting aside for the moment the difficulties that arise when the regular vertical spacing of the bands is taken into account, the bearing of other field evidence may be mentioned.

The general mode of occurrence simulates bedding, but as W. Hill[4] and others have pointed out there is such a close correspondence between the grain, micro-structure, and faunal content of the flint and Chalk that these observers have expressed their belief that the flint is replacive in its attitude to the Chalk. This is quite consistent with penecontemporaneous formation.

On the other hand, the well-known occurrence of exactly similar flint in vertical or highly inclined planes[5] is difficult to reconcile with any other view except that according to which the flint was formed later than the complete deposition of the Chalk. There is no difference between the two types of flint. Sometimes the line of the crack can be seen running through the flint, but where the nodules bulge out they show the same replacive features as do the horizontal flints. This "vein" flint is most commonly observed in anticlinal areas, and the cracks conform in direction to the other tectonic features. They are thus directly related to uplift, and point to the formation of the flint at that time, so supporting Liesegang's contention. Moreover, there are certain puzzling types of nodule (paramoudras, pot-stones, flint rings) which are by no means easy to understand as original deposits. And it may be mentioned that although carefully sought for in both oceanic and shallow water, no flint either partially or completely formed has been dredged up.[6] On the other hand, in both the Upper and Middle Chalk masses of chalk of flint-like form have been found in all stages from white silicified chalk, with perhaps just a small central core of black flint, to the completely black nodule—facts strongly supporting a replacement hypothesis.

The evidence,[7] so far as it goes, seems to me to be decidedly in

[1] G. W. Bulman, Sci. Prog., No. 41, 1916, p. 154.
[2] W. A. Tarr, Amer. Journ. Sci., ser. IV, vol. xliv, p. 428, 1917.
[3] F. M. Van Tuyl, Amer. Journ. Sci., ser. IV, vol. xlv, p. 449, 1918.
[4] W. Hill, Proc. Geol. Assoc., vol. xxii, p. 62, 1911.
[5] A. D. Rowe and C. D. Sherborn, Proc. Geol. Assoc., vol. xvi, p. 170, 1900. W. J. Sollas, *The Age of the Earth*, London, 1905, p. 135.
[6] J. Murray and J. Hjort, *Depths of the Ocean*, London, 1912, pp. 183–5.
[7] See also E. Ray Lankester and others, discussion in *Nature*, 1917, reprinted in Trans. Geol. Physics Soc., 1917.

favour of the replacement of the chalk by silica at the time of uplift. Consideration of the remaining questions will be found to strengthen rather than oppose this conclusion.

3. The Source of the Silica.[1]

Some suggestions as to possible sources of the silica may be dismissed: such, for instance, that it was deposited by percolating sea-water. Magmatic sources are excluded at any rate from the English Chalk. Moore's[2] suggestion that the silicates of overlying strata decomposed by carbonated water furnished the supply has no geological evidence to support it.

Sollas,[3] among recent writers, treating the subject quantitatively, has maintained that the silica was derived from the tests and other remains of siliceous organisms scattered through the Chalk. Jukes-Browne always opposed this theory of disseminated silica, as he called it.[4] Tarr more recently favoured the direct chemical precipitation of silica from sea-water, and was impressed apparently by the immense amount of silica present as chert.

Jukes-Browne, as the result of analyses, stated definitely that "there is no inverse relation between the abundance of flint and the presence of disseminated silica". Since no later analyses seem to be available I have abstracted in Table No. 1 those given by Jukes-Browne himself. However, analyses of certain very siliceous beds in Wiltshire have been omitted. Three of these give respectively 39, 19, and 17 per cent of soluble silica, and inclusion of them would considerably raise the mean percentage of available soluble silica. The analyses in the table are plotted in one of the curves of Fig. 1—the percentage silica horizontally and the height of the sample above the base of the Chalk vertically. It will be noticed that there is a marked increase in soluble silica reported in all analyses below the Melbourn Rock.

Turning now for a moment to consider the amount of silica represented by the flint, I have made an estimate based on the Kent section, since details are available which give almost complete measurements for the whole of the Kent Chalk. The details of this estimate will be found in Table No. II. In this table some columns are devoted to a statement of the assumptions made when details are not available. Assumptions have sometimes to be made as to the number of bands present, their mean thickness, and the amount of flint in each band. In making these estimates I have been guided by actual statements available for the same zones in neighbouring districts, and by my own observations, chiefly in the London area. The mean results for each zone are plotted on the second curve in Fig. 1 to the same scales as the soluble silica.

[1] In what follows numerical data relating to the Chalk, unless otherwise stated, have been obtained from A. J. Jukes-Browne, *Cretaceous Rocks of Britain*, Mem. Geol. Surv.; and from the papers on the White Chalk of the English Coast in the Proc. Geol. Assoc. (1899–1903), by A. R. Rowe and C. D. Sherborn.

[2] B. Moore, Trans. Geol. Physics Soc., 1917, p. 1.

[3] W. J. Sollas, *The Age of the Earth*, London, 1905, pp. 132–65.

[4] A. J. Jukes-Browne, Geol. Mag., 1893, p. 541.

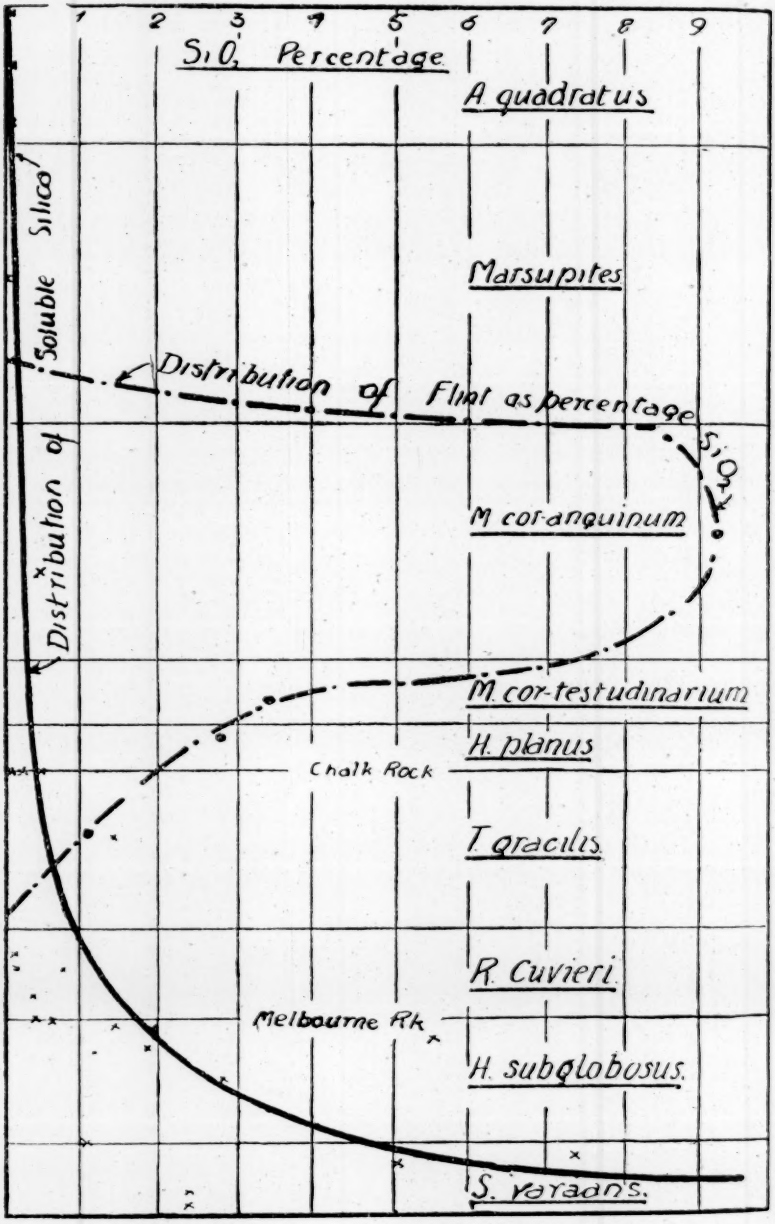


FIG. 1.—Comparison between the silica distributed in soluble form through the Chalk and that present as flint.

A comparison of these curves will bring out the following points:—

(*a*) The flinty chalk and the flintless chalk *above* it are both poor in soluble silica.

(*b*) Increased values in the Lower Chalk appear just where the flint is dying out.

The curves suggest that there *is* an "inverse relation" between the relative amounts of flint and soluble silica present, and that it is a very striking one. Jukes-Browne compared only flinty and flintless zones of the Upper Chalk, but it is obvious that the whole of the Chalk must be considered, because in this case the comparison suggests that the flint represents the silica once spread out in its own region and in the flintless beds above it.

If we now test quantitatively the hypothesis that the silica required for flint formation was obtained from that disseminated in the Chalk itself, it will be found that the analyses in Table No. 1 give the following averages:—

Below the Melbourn Rock, mean silica . . 2·9 per cent.
Above the ,, ,, ,, . . 0·3 ,, ,,

There is thus a balance of some 2·5 per cent in the lower part, which might reasonably be assumed to represent the minimum amount of silica originally available for the formation of flint. It may be noted that this amount is of the same order as the 2 per cent estimated by Mortimer[1] as available for the Chalk of Yorkshire, and as the observation of Sollas that the Upper Chalk may contain as much as 3 per cent of hollow casts of spicules.[2] The exceedingly siliceous beds of the Lower Chalk are here left out of account, but it must be remembered that such rich beds may originally have been present in the Upper Chalk. Indeed, the occasional occurrence of desilicified sponge beds rather points that way. Moreover, if modern oozes are any criterion as much as 10 per cent of silica in organic form is a not unreasonable figure for the original amount, and it might become necessary to account for the disappearance of a portion. In that case part of the original silica, instead of forming concretions, may easily have been carried off in solution, or have been partially dissolved on the sea-floor, as Murray has recorded for modern deposits.[3]

Taking, however, the 2½ per cent above as a conservative figure, my estimate for the 557 feet of flinty chalk in Kent gives a mean percentage flint content of 6 per cent. And, although there may be elsewhere a greater thickness of flinty beds, there is not, I think, a greater concentration of flint. The amount of flint to be accounted for is not, therefore, enormous, and if disseminated through the whole thickness of existing Chalk would be not much more than 2 per cent. It would, to put it in another way, require about 1,300 feet of Chalk to supply the Kent section, that is less than 700 feet above the flinty region. And if Sollas's figure of 5,000 feet for the minimum thickness of Chalk is correct there was ample for the purpose.[4]

[1] R. Mortimer, Proc. Geol. Assoc., vol. xxi, p. 96, 1910.
[2] W. J. Sollas, *The Age of the Earth*, London, 1905, p. 147.
[3] Ibid., p. 160.
[4] J. Murray and J. Hjort, loc. cit., pp. 183–5.

There yet remains one further matter which I think has not hitherto been discussed, namely, the history of the carbonate set free if the flint is a replacement of the Chalk. There are one or two interesting facts in this connexion, though no special emphasis should perhaps be laid on them. Jukes-Browne states that calcite is abundant in the *gracilis* and *planus* zones of Yorkshire, and that it is not uncommon in the Chalk Rock.[1] It has also been observed in the lower zones of the south. There are no quantitative observations, but it is significant that it should be several times reported in the lower zones. However, it is by no means necessary to suppose that the replaced carbonate is represented by calcite. It may in part be present as a cementing material in the Chalk, for there is usually about 30 per cent of pore space. It is therefore curious to note that whilst the Upper Chalk of the South is usually described as soft and friable, the bulk of the building stones are quarried in the Middle and Lower Chalk.[2]

4. The Rhythm of the Flint Bands.

The regularity of the recurrence of bands of flint in the Chalk attracted early attention. Many theories have been framed in the past to account for this periodicity of flint, and indeed no theory which neglects to take into account this obvious feature is likely to be generally accepted. Most of the earlier theories looked to periodic organic growth or to periodic precipitation from the sea. But there is no adequate external cause for this periodicity except a seasonal one, and Cole and others have shown the incompetence of this.[3] It is the simplicity of the Liesegang explanation of the rhythm that makes a re-examination of the evidence for possible support desirable. Before discussing the matter further, it is necessary to examine Liesegang's results and to summarize some recent work on precipitation in gels.[4]

If a gel, in which silver chromate has been precipitated rhythmically, or one of Liesegang's figures, be examined, it will be seen that near the entrance of the inward-diffusing solution the bands are so close together that they appear as a continuous precipitate, though they can usually be resolved by magnification. Passing outwards the banding is obvious to the naked eye. By measurement of one of Liesegang's[5] figures and plotting the amount separating the bands against their distance from the drop, as in Fig. 2*a*, a picture of the rhythm is obtained. It will be seen from this curve that the rhythm can be divided into two stages—

AB = near the origin. The bands so close as to appear continuous.

BC = Bands with the separation increasing approximately according to a linear law.

[1] A. R. Rowe and C. D. Sherborn, Proc. Geol. Assoc., vol. xvii, p. 229. A. J. Jukes-Browne, Geol. Mag., 1893, p. 317.

[2] J. A. Howe, *Geology of Building Stones*, London, 1910, p. 259.

[3] G. A. J. Cole, loc. cit.

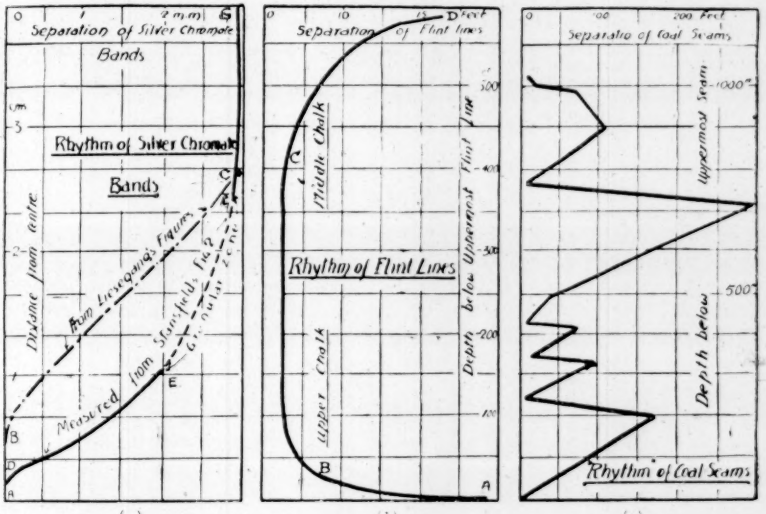
[4] For a simple and clear account of precipitation in gels see E. Hatschek, *Introduction to the Physics and Chemistry of Colloids*, 2nd ed., London, 1916.

[5] R. Liesegang, loc. cit., chap. x.

In a recent paper J. Stansfield, working with gels and solutions of different concentration, has added considerably to our knowledge of the rhythm. The following among his conclusions may be noted :—

(*a*) Increase in the distance between the bands is due to progressive dilution of the reagent, and the rate of diffusion is an important controlling factor. Under certain conditions the bands may be equally spaced, or spaced at decreasing distances.

(*b*) Banding may sometimes break down altogether, and be replaced by a granular zone. This, again, may be followed on further diffusion by a resumption of banded precipitation.



(*a*) Bichromate Gels. (*b*) Flint in Chalk. (*c*) Coal-seams.

FIG. 2.—Rhythm curves obtained by plotting distance separating bands against the position of bands measured from a chosen origin.

Now measuring up Stansfield's Fig. 2, and plotting the results besides those of Liesegang, the rhythm-curve given in Fig. 2*a* is obtained.[1] There is the closely banded stage AD as before; a stage DE of increasing separation not quite linear; a granular zone EF where the precipitate is in spots scattered throughout the zone without linear or other arrangement; and a final region FG where the precipitate is in bands separated by constant intervals, but much greater than in the earlier banded stage DE.

We may now return to a consideration of the Chalk. In Fig. 3 I have constructed vertical sections for three coastal localities, putting in the position of the flint bands. Quantitative data are available for practically the whole of the Kent section, and in the others it is possible to fill satisfactorily the gaps in the measurements by qualitative statements, which are fortunately abundant. Now all of these show a sufficiently striking resemblance to the

[1] J. Stansfield, Amer. Journ. Sci., ser. IV, vol. xliii, p. 1.

precipitation of silver chromate bands in vertical tubes. Treating these measurements in the same way as those from the gels the rhythm-curve of Fig. 2*b* is obtained. Here the amount of separation of flint lines is plotted against their distance below the top flint line (since the curves of Fig. 1 suggest a downward diffusion). This curve is slightly generalized to show the characteristics of all the sections of Fig. 3. The rhythm may be analysed into three main stages, starting from the entry—

(*a*) AB, on the curve. Separation of the bands decreasing downwards.

(*b*) BC, dense banding. The bands separated by intervals nearly constant, but varying slightly between 2 and 3 feet.

(*c*) CD, the separation of the bands increasing downwards. There is also a marked tendency to the development of granular zones in stages 1 and 2.

This rhythm, therefore, differs from that which obtains in the gels by the addition of an earlier stage with *decreasing separation* of the bands. On the other hand, it is so definite that it can hardly be accidental. Moreover, the same rhythm will be repeated more or less perfectly, not only in the sections figured, but also in any other which is of sufficient length and where details are sufficient to apply the test. It is interesting to treat a coal-shaft section in the same way for comparison. In Fig. 2*c* the rhythm curve from a South Wales mine is given[1]—the intervals separating seams being plotted against their depth below the first seam. If the occurrence of long intervals separated by a series of short ones be taken as a kind of periodicity, it is obviously of a character vastly differing from that shown either in the Chalk or in the gels. At the same time this comparison brings out still more strikingly the close similarity of the phenomena in the last two cases.

It is not my purpose to speculate on the nature of the chemical reactions which took place. Liesegang supposes that at the time of uplift the Chalk was permeated by a solution of silica, which in the light of the results of the previous section we may suppose to be furnished by a partial solution of organic remains in the Chalk. The uplift caused a downward draining, and either the solution reached a supersaturated state or accumulated a precipitant. In either case the solution was precipitated rhythmically. In the early stage AB of the flint-rhythm (applying Stansfield's results) there was probably progressive increase in the concentration of the reacting solutions, accompanied by decreasing separation of the precipitation bands. There followed the zone of most favourable concentration and densest precipitation, and later progressive dilution of the solutions brought on a gradual lengthening of the separation interval. This sequence in the banding is curiously reflected in the character of the flints in the various zones. Where flints occur in the *mucronata* zone and the Chalk above they are generally small, often spongiform (as though "sowing" had caused the precipitation of a solution in the metastable state); and formed of immature flint. Scattered

[1] *South Wales Coalfield* (Mem. Geol. Surv.), pt. viii, p. 113, 1907.

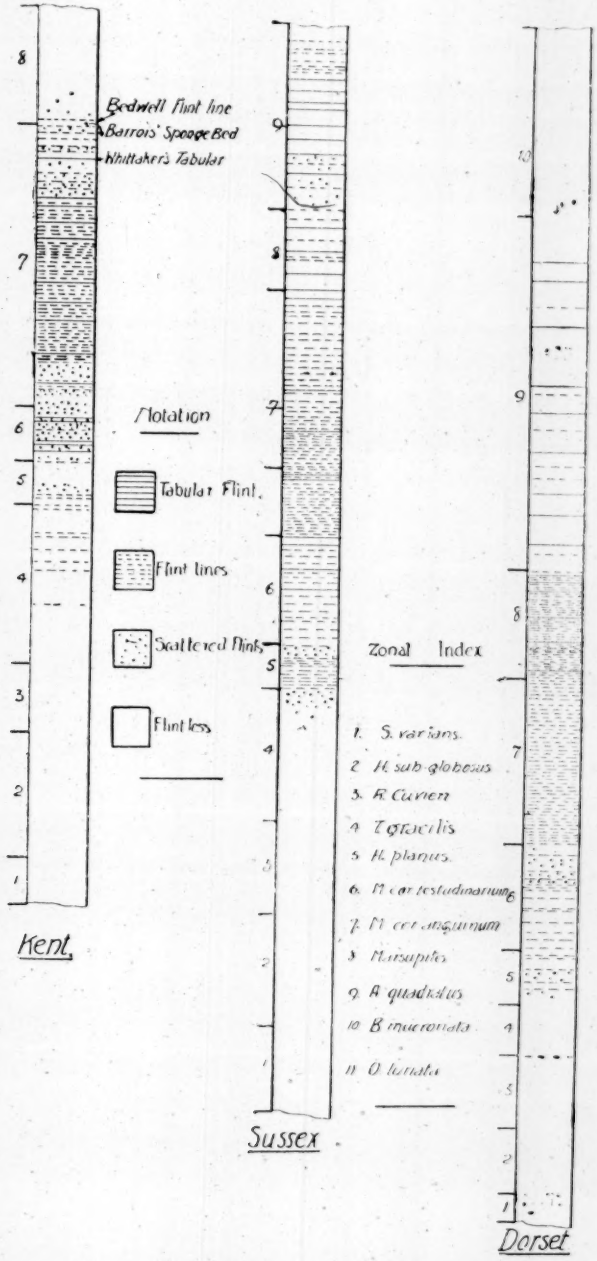


FIG. 3.—Vertical distribution of Flint in the Chalk.

flints corresponding to "granular zones" are common. In the *Marsupites* and *cor-anguinum* zones solid flints are the rule and continuous flint bands are common. In the lower parts of the latter zone carious flints become more common and prevail in the *gracilis* and *planus* zones, where the flints are also spongiform, often scattered, and immature. Thus the opening and closing phases of the sequence are characterized by enfeebled flint development as well as by a wide interval between the bands.

It may be mentioned that such types as banded flints, paramoudras, and flint rings present less difficulty when considered as rhythmic phenomena, and some of them have already been imitated in gels.

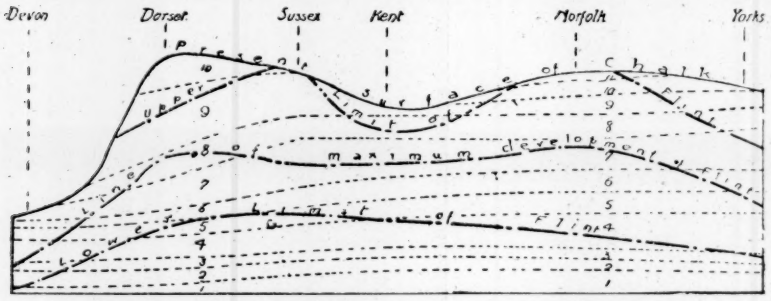


FIG. 4.—Horizontal distribution of Flint in the Chalk.
(The zonal numbers are the same as those used in Fig. 3.)

If the distribution of the flint be studied in a horizontal section, such as that given in Fig. 4, some rather interesting relations are brought to light. In drawing the section the Chalk has been reduced to a horizontal base. The zonal boundaries are shown in dotted lines. The chain-dotted lines represent the upper and lower limits of flint occurrence and the approximate line of its maximum development.

Now it will be apparent that the lines of flint development transgress the zonal boundaries. If the flint had been deposited contemporaneously with the Chalk, one would expect it to conform horizontally to the zones, and its failure so to do strongly supports the view that the flint is later in date than the deposition of the Chalk.

There is, moreover, a curious but rather striking tendency of the flint development lines to follow the present surface of the Chalk. If the flint bands are due to periodic organic growth, or to periodic chemical precipitation, there is no reason why its horizontal distribution should show such a characteristic. On the other hand, if we suppose the present surface to be related more or less remotely to the surface at the time of uplift, it would mean that the lines of flint development were also related to that surface. Such behaviour is not merely in conformity with the theory of rhythmic precipitation of solutions diffusing through the Chalk under draining actions due to uplift, but might be predicted as a result to be expected of such action.

TABLE No. 1.

Horizon.	Locality.	Soluble SiO_2 per cent.
Belemnitella mucronata . .	Corfe Castle . . .	0·10
,, ,, . .	Studland, Dorset . .	0·11
Actinocamax quadratus . .	Otterburn, Hants . .	0·10
Marsupites testudinarius . .	Bishop's Down, Wilts .	0·00
Micraster	Great Dunford, Wilts .	0·50
Chalk Rock	Aston Rowant, Oxon .	0·48
,, ...	Redburn Hills, Wilts .	0·05
,, ...	Boxmoor, Herts . . .	0·13
Terebratulina gracilis . .	Royston, Herts . . .	1·48
Rhynchonella Cuvieri . .	300 feet above Gault, Wye .	0·04
,, ,, ...	St. Catherine's Hill, Winchester . . .	0·06
,, ,, ...	Hitchin	0·72
,, ,, 50 feet above Melbourn Rock . . .	Hitchin	0·35
Melbourn Rock, upper part .	Okeford Fitzpaine, Dorset .	0·45
,, ,, lower part .	,, ,, .	0·65
Belemnite Marl, chalk between marls	Hitchin	1·53
Belemnite Marl, chalk between marls	Royston	1·90
Belemnite Marl (lower) . .	Hitchin	5·57
,, ,, (chalk just below)	Arlesey, Hitchin . .	1·81
20 feet below Melbourn Rock .	Brimsdown, Wilts . .	1·15
50 feet below ,, .	Belchalwell, Dorset . .	2·95
Totternhoe Stone . . .	Arlesey, Hitchin . . .	1·02
6 feet below Totternhoe Stone .	,, ,, . . .	1·41
20 feet below ,, .	,, ,, . . .	7·30
Schloenbachia varians . .	Warminster, Wilts . .	6·68
,, ,, . . .	Upper Scudamore, Wilts .	2·28
Chloritic Marl	Farnham, Surrey . .	2·16

5. Summary.

1. An examination of the amounts of silica disseminated through the Chalk and segregated as flint reveals a distinct and striking inverse relation between them.

2. The amount of silica present as flint is found to be of the same order as that disseminated, and confirms the conclusions at which Professor Sollas has already arrived. The silica, that is, might easily have been derived from the remains of siliceous organisms buried in the Chalk, and only requires a moderate thickness for the supply.

3. The rhythm found in the recurrence of flint lines presents a striking similarity to the Liesegang banding; and in general a study of flint distribution strongly supports the hypothesis that the flint originated by the rhythmic precipitation of solutions diffusing through the Chalk at the time of uplift.

Whether these conclusions apply to flint-like segregations in other formations it is impossible to say, since there is no such body of quantitative data available for their study as exists for that of the

TABLE No. 2.

Zone.	1	2	3	4	5	6	7	8
			Inches.	o/o	ft. in.	ft. in.	o/o	Feet.
Marsupites.	Few scattered several feet above base	1	12	100	1 0			
	Bedwell Line. 4 inches. Flints scattered	—	—	50	2	1 2	—	60
Micraster cor-anguinum.	2 in. layer	—	—	50	1			
	Layer	—	3	50	1½			
	Layer	—	3	50	1½			
	Whitaker's tabular, 3 in.	—	—	100	3			
	Few layers	6	3	50	9			
	Columnar tabular	—	4	100	4			
	80 layers	—	3	100	20 0			
	Irregular layers and scattered flints	4	3	50	6			
	Tabular, 2 inches	—	—	100	2			
	Scattered through 15 feet	3	3	50	5	22 9	9·3	246
Micraster cor-testudinarium.	Scattered through 26 feet	7	2	50	7			
	Tabular	—	2	100	2			
	Scattered through 15 feet	3	3	50	5			
	Strong flint line	—	5	50	3			
	Two broken bands	—	2	50	2			
	Strong flint line	—	5	50	3	1 10	3·3	56
Holaster planus.	Scattered through 15 feet	5	2	50	5			
	Layer, 4 inches thick	—	—	50	2			
	,, ,,	—	—	50	2			
	Flint line, 4 inches thick	—	—	50	2	11	2·7	34
T. gracilis.	Flint line	—	4	50	2			
	Irregular lines	12	3	50	1 6			
	Flint line	—	4	50	2	1 10		161
	Total for whole section					28 6	5·1	557

1. Remarks on character of flint bands with any actual measurements available.
2. Assumed number of bands present.
3. Assumed thickness of band.
4. Allowance for amount of flint in band.
5. Total thickness of flint if solid, calculated from previous columns.
6. Total thickness of solid flint in the zone.
7. Percentage flint per zone. (Plotted in Fig. 1.)
8. Thickness of zone. (Flinty *Marsupites* Chalk less than 60 feet.)

English Chalk. I have refrained from discussing in this paper theories recently advanced to account for the origin of chert, partly because of this lack of data as regards the formations in question, and partly because the authors make no attempt to account for any regularity in the recurrence of nodular lines. It may be that in the formations discussed in these papers such periodicity is not apparent. But so far as the English Chalk is concerned, this is one of the most obvious features and an explanation of it may reasonably be required of any hypothesis advanced as to flint origin.

My thanks are due to Professor H. H. Swinnerton, D.Sc., for critically reading this paper in MS.

IV.—The Correlation of the Devonian Rocks of North Devon with those of other localities.

(Abstract of communication to Section C, British Association, 1919.)

By Dr. John W. Evans, F.R.S.

THE Dartmouth Slates of South Devon and Cornwall, which correspond, it would seem, to the Schistes d'Oignies of the Ardennes, are not seen in North Devon, but may be concealed by later rocks and be represented in South Wales and the Welsh Border by the Red Marls of the Lower Old Red Sandstone. It is possible that the Foreland Grits are a local facies of the upper portion of the Dartmouth Slates, just as the arenaceous Cosheston Group is a local development of the upper part of the Red Marls. Both the Foreland Grits and the Cosheston Group appear to have yielded the typical Old Red Sandstone plant *Psilophyton*.[1]

The usual correlation of the Lynton Beds with the Meadfoots of South Devon seems well founded. The lower beds with *Pteraspis* may be compared with the Schistes de Saint Hubert of the Ardennes with *Spirifer primævus* and *Pteraspis dunensis* and the Schistes à *Pteraspis dunensis* in the Pas de Calais. The Senni Beds, which overlie the Red Marls on the north of the South Wales Coalfield and contain *Pteraspis* and *Cephalaspis*, may be of the same age. The two strata last mentioned have not, however, up to the present yielded any marine forms.

The Hangman Grits represent a great thickness of arenaceous beds of the Old Red Sandstone type overlying the Lynton Beds. Little is known of the lower portion, but the upper beds include lacustrine or fluviatile beds, with plant remains which are probably referable to the Middle Devonian plant *Ptilophyton*. These are succeeded by marine beds with several fossiliferous horizons, some of which have yielded *Stringocephalus*. The upper part at least of the Hangman Grits must therefore be considered to be of Givetian age, that is to say, Upper-Middle Devonian, instead of Upper-Lower Devonian, according to the usual correlation. This view is supported by the discovery near Combe Martin (after the reading of the paper) in the

[1] The author is not inclined to accept the view that the Foreland Grits are a repetition of the Hangman Grits, by faulting.

plant-bearing beds of a fish-plate referred by Dr. Smith Woodward to *Coccosteus*, a genus which is usually of Middle Old Red Sandstone and Middle Devonian age, though it has been found in the Upper Old Red Sandstone. The Staddon Grits of South Devon, on the other hand, which are usually considered to be the equivalent of the Hangman Grits, cannot extend upwards much above the base of the Eifelian or Lower-Middle Devonian, as they are succeeded by dark-grey slates and shaly limestones with *Calceola sandalina*. The succession in the Middle Devonian of North Devon may be paralleled in the Boulonnais, where micaceous sandstones with plant remains are overlaid by marine beds with *Stringocephalus burtini*.

The Hangman Grits are succeeded by the Combe Martin Beds, grits with occasional ferruginous crinoidal limestones, and these by the Ilfracombe Beds, shales and limestones with crinoids and corals. Except for an alleged occurrence of *Stringocephalus*, which cannot now be verified, no distinctive fossils have been found either in the Combe Martin or Lower Ilfracombe Beds, and they may be either Upper-Middle Devonian (Givetian) or Lower-Upper Devonian (Frasnian). Unfortunately no goniatites have been found in the Devonian of North Devon, so that exact correlation is difficult. In higher portions of the Ilfracombe Beds *Spirifer verneuili* and *Rhynchonella* (*Wilsonia*) *cuboides* are found, which are sufficient to establish the Upper Devonian (presumably Frasnian) age of the rocks. The highest Ilfracombe Beds are less calcareous, and there seems no reason to doubt that they pass upwards conformably into the Morte Slates, the Upper Devonian age of which is completely established by the occurrence of *Spirifer verneuili* (var. *hamlingi*), and they may well represent the Schistes de Matagne, which form the highest beds of the Frasnian in the Ardennes. Rocks of the same age appear to be met with in the Boulonnais and in the boring in Tottenham Court Road in London. The Morte Slates become more arenaceous at the summit and are succeeded probably conformably by the Pickwell Down Sandstones. The junction is usually faulted, but this is apt to be the case in strongly folded areas where successive beds differ considerably in physical characters and in the resistance they offer to the forces to which the rocks have been subjected. The Pickwell Down Sandstones have yielded the typical Upper Old Red Sandstone fish *Holoptychius* and *Bothriolepis*, and may be compared to the beds with the same forms reached by a boring at Southall, west of London, and to the Psammites de Condroz. They must therefore be referred to the terrestrial or Old Red Sandstone type of the Famennian. The Baggy and Marwood Beds that overlie the Pickwell Down Sandstones and the lower portion of the succeeding Pilton Beds represent a marine facies of the Upper Famennian, as well as the Calcaire d'Étroeungt, which forms a passage to the Carboniferous in the Ardennes. The Upper Devonian of the Turnford boring in the Lea Valley, north-east of London, and the marine beds of the Upper Old Red Sandstone of South Wales and the Coomhola Grits in South Ireland are probably at about the same horizon as the Baggy and Marwood Beds and the base of the Piltons. The Upper Pilton Beds have now been shown to be of Carboniferous and not Devonian age,

and to extend upwards and include the basement beds of the *Zaphrentis* zone.

It will be seen that North Devon is characterized by a repeated alternation of the terrestrial or Old Red Sandstone facies formed of materials laid down by rivers or in lakes, or transported by the action of the wind, and the marine facies of the Devonian. This alternation is even more remarkable than that in the Eastern Baltic, with which all students of geology are familiar. There were, as we have seen in North Devon, three periods when the marine recession resulted in the deposition of the Old Red type of sediment with fresh-water fossils, the first commencing in some areas towards the close of Silurian times and continuing through the Gedinnian, the second including the uppermost horizons of the Lower Devonian and apparently the whole of the Eifelian, and the third in the Famennian. Each recurrence of the terrestrial facies is characterized by a completely different fauna and flora. There were also three periods of marine transgression, one, which is missing in the Baltic area, about midway in the Lower Devonian, the second in the Givetian and Frasnian, and the third commencing near the close of the Famennian and reaching its maximum in the Carboniferous. In South Devon and Cornwall the conditions as a whole were more marine than in North Devon, and it was only during the deposition of the Dartmouth Slates in North Cornwall that entirely terrestrial (here freshwater) conditions prevailed. In South Wales, on the other hand, terrestrial conditions were more prevalent than in North Devon ; but a far more important difference between the north and south of the Bristol Channel lies in the complete omission, due either to non-deposition or erosion, of any representative of North Devon ; strata from at least low down in the Lynton Beds to the summit of the Morte Slates.

The variation of conditions of deposition which are so strongly marked in North Devon can be traced in most of the occurrences of Devonian rocks in other parts of the world, though they are nowhere else so striking and unambiguous. It is the deepening and transgression of the sea in Givetian and Frasnian times that is the most widely extended and most strongly marked of all these changes.

The Devonian period is not a natural division of the history of marine sedimentation characterized by a gradual deepening and subsequently a gradual shallowing of the ocean waters, but was determined solely by the interval between the last marine beds of the Silurian and the earliest marine beds of the Carboniferous Limestone on the Welsh Border, where these strata were first studied in the early days of stratigraphical research. It was in this way that the limits of the Old Red Sandstone were originally fixed, and as a consequence also those of the contemporaneous rocks of marine origin elsewhere deposited, which were a little later grouped together to form the Devonian.

V.—On the Discovery of Fossil Hydroid Remains of the Order Calyptoblastea in the Palæozoic of Victoria, Australia.

(PLATE XV.)

By Frederick Chapman, A.L.S., Palæontologist to the National Museum, Melbourne, and Professor Ernest W. Skeats, D.Sc., A.R.C.S., F.G.S., University of Melbourne.

SINCE no undoubted fossil remains of this group of hydroids have been previously recorded, with the exception of possible forms indicated by Ruedemann but placed by him with the Graptolites, it is thought that a few brief notes on a recent discovery in Victoria may be acceptable to readers of this Magazine. A description of the fossils by one of us (F. C.) will appear in the Proc. Roy. Soc. Victoria, while a description of the stratigraphy of the area will be given by the other author (E. W. S.)

Rocks in which the Fossils occur.

The fossils are found in a black shale about 2 miles north-east of North Monegetta and 2½ miles south-east of Romsey railway stations and about 40 miles north of Melbourne. The black shale occurs as vertical outcrops in Deep Creek, striking, N. 20° E., interbedded with black cherts and in conformable contact with Heathcotian (Cambrian) diabase which forms Hurst's Hill east of Deep Creek. The fossils are associated with a Brachiopod *Acrotreta antipodum*, Chapm., which suggests a horizon low down in the basal Ordovician, but somewhat similar branching forms occur with *Dinesusida* and other trilobite remains of probably Cambrian age near Heathcote, about 30 miles further north.

Condition of Fossils.

The remains of the hydrosome are seen as a silvery-white film on the dark slate. In the case of *Mastigograptus* this film is very tenuous and seems to disappear rapidly into the slaty surface, though under a lens the thecal growth can be seen extended for quite a distance. The shape of the aperture of the cups of both hydrothecæ and gonothecæ is distinct.

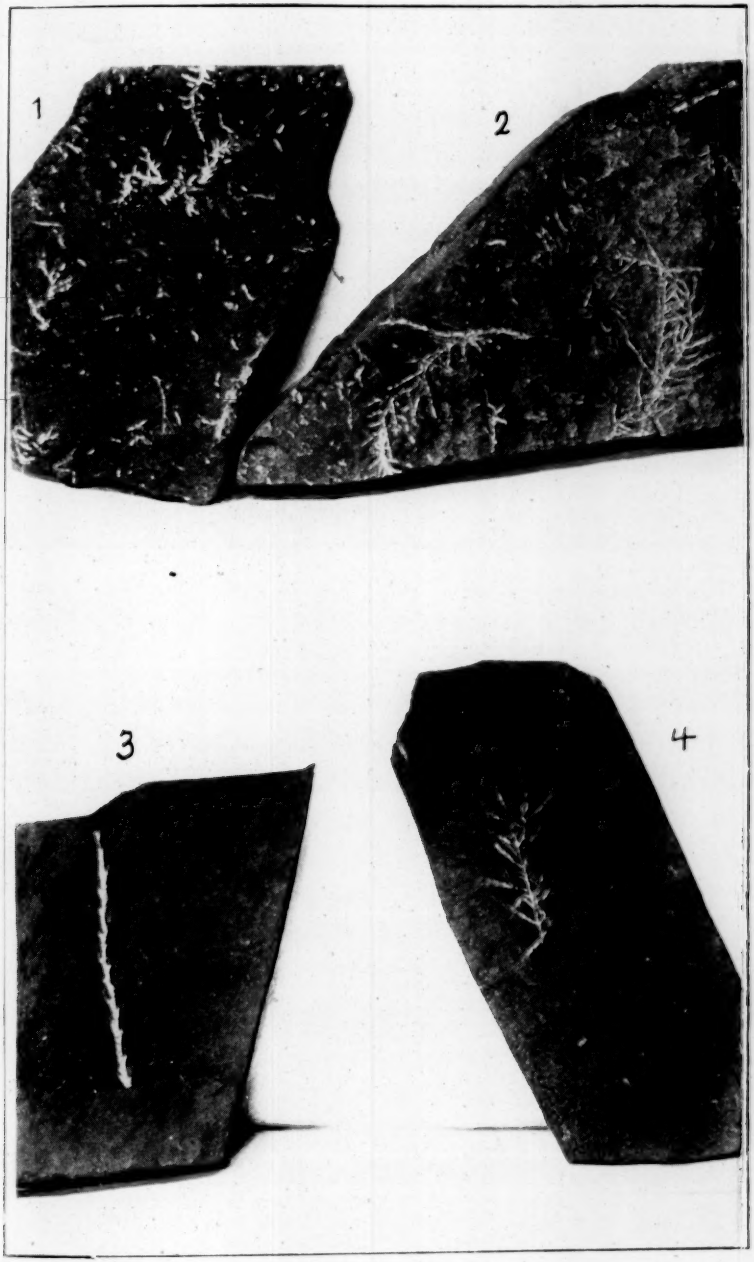
Definition and Relationships.

Comparing these Palæozoic fossils with living hydroids, two generic forms seem to be closely related to living genera, and are accordingly named *Archæocryptolaria* (*A. skeatsi*) and *Archæolafoëa* (*A. recta* and *A. longicornis*). *Archæocryptolaria* resembles in its long, cylindrical hydrothecæ *Cryptolaria angulata*, Bale, a living form found in the Great Australian Bight at 100 fathoms. *Archæolafoëa* is compared with the living *Lafoëa fruticosa*, Sars. *Mastigograptus* was described by Ruedemann from the Utica Slate of Trenton, New York (Middle Ordovician). *M. monegettæ* shows less tendency to branch than in *M. tenuiramosus* of Ruedemann.

EXPLANATION OF PLATE XV.

Fig. 1.—*Archæocryptolaria skeatsi*, Chapm.
,, 2.—*A. longicornis*, Ch.
,, 3.—*A. recta*, Ch.
,, 4.—*Mastigograptus monegettæ*, Ch.

From black shale in the basal Ordovician near North Monegetta, 40 miles north of Melbourne, Victoria. Figures slightly enlarged.



J. C. phot.

NEW FOSSIL HYDROIDS FROM THE PALÆOZOIC OF VICTORIA.

VI.—British Association for the Advancement of Science, Bournemouth, 1919.

Address to the Geological Section. By J. W. Evans, D.Sc., LL.B., F.R.S., President of the Section.

(*Concluded from p. 517.*)

ANOTHER direction in which the work of the Survey could with advantage be extended is in the execution of deep borings[1] on carefully thought-out schemes by which a maximum of information could be obtained. Both in Holland and Germany borings have been carried out to discover the nature of the older rocks beneath the Secondary and Tertiary strata, and Professor Watts, in his Presidental Address to the Geological Society in 1912 (Proc. Geol. Soc., pp. lxxx–xc), has dwelt on the importance of exploring systematically the region beneath the wide spread of the younger rocks that covers such a great extent of the East and South of England. Professor Boulton, my predecessor in this Chair, has endorsed this appeal, but nothing has been done or is apparently likely to be done in this direction. It seems extraordinary that no co-ordinated effort should have been made to ascertain the character and potentiality of this almost unknown land that lies close beneath our feet and is the continuation of the older rocks of the west and north to which we owe so much of our mineral wealth. It is true that borings have been put down by private enterprise, but, being directed only by the hope of private gain and by rival interests, they have been carried out on no settled plan, and the results and sometimes the very existence of the borings have been kept secret. The natural consequences of this procedure have been the maximum of expense and the minimum of useful information.

Unfortunately in recent years percussion or rope boring, which breaks up the rock into fine powder, has more and more, on account of its cheapness, replaced the use of a circular rotating drill which yields a substantial cylindrical core that affords far more information as to the nature of the rocks and the geological structure of the district. If private boring is still to be carried on, the adoption of the latter procedure should be insisted on, even if the difference of cost has to be defrayed by the Government. It is quite true that a considerable amount of useful information can be collected by means of a careful microscopic examination of the minute fragments which alone are available for study, so that the nature of the rocks traversed can be recognized; but the texture of the rock is destroyed, as well as any evidence which might have been available of its larger structures and stratigraphical relations, and almost all traces of fossils. It is, too, impossible to tell with certainty the exact depth at which any particular material was originally located, for fragments broken

[1] I have not space to deal here with the shallow borings in soft strata which have been so successfully conducted on the Flanders front during the War by Captain W. B. R. King, of the Geological Survey. Similar borings have been already carried out by the Survey on a limited scale, but in the light of the experience that has now been gained we may look for a widely extended use of the method both by private workers and by the Survey officers.

off from the sides of the bore may easily find their way to the bottom.

A good illustration, and one of many that might be cited, of the misdirected energy that is sometimes expended in prospecting operations, was afforded a few years ago by a company that put down a boring for oil through more than a thousand feet of granite without being aware of the nature of the rock that was being traversed. In this case a percussion drill was employed, but a few minutes' examination of the material should have enabled the engineer in charge, supposing he had even an elementary knowledge of geology, to save hundreds of pounds of needless expenditure. The sum-total of the funds which have been uselessly expended in this country alone in hopeless explorations for minerals, in complete disregard of the most obvious geological evidence, would have been sufficient to defray many times over the cost of a complete scientific underground survey.

If research is to be carried out economically and effectively, it must be organized systematically and directed primarily with the aim of advancing knowledge. If this aim be well and faithfully kept in view, material benefits will accrue which would never have been thought to be sufficiently probable to warrant the expenditure of money on prospecting.

It is, however, not only in the areas occupied by Secondary or Tertiary rocks that systematic boring is urgently needed. There are many other localities where important information as to the structure of the rocks could probably be obtained in this manner. Opinion is very much divided as to the relation of the Devonian to the older rocks in South Devon and Cornwall,[1] but there is little doubt that a series of judiciously placed borings would solve the problem without difficulty. In North Devon and West Somerset, the question as to whether the Foreland Grits are a repetition by faulting of the Hangman Grits could also be settled at once by borings in the Foreland Grits and in the Lynton Beds.

In the North of England, again, there are many points where the strata exposed at the surface are low down in the Carboniferous, and it would be comparatively easy to ascertain the nature of the earlier rocks beneath them, with regard to which we are much in need of information.[2]

[1] I have already referred to the economic importance of this area. The desirability of ascertaining its true geological structure is too obvious to need emphasis here.

[2] The recent borings for mineral oil in the Carboniferous rocks of Derbyshire were put down largely by means of public funds, and such success as they have attained has been due to the fact that they were directed by expert geologists; but there can be little doubt that, if they had been carried out as part of a carefully thought-out scheme of underground exploration wherever it was needed to elucidate the structure of the country, economies would have been effected and the sum-total of our knowledge even from the economic standpoint would have been far greater. It is a pity that these borings have been carried out by means of the percussion process. It is, however, usually employed in borings for oil—in America almost exclusively—and in war-time its greater speed was no doubt an important factor in the decision to resort to it.

It would be easy to cite other cases where information of considerable geological value could be obtained by boring at comparatively small expense, and would, in all probability, in the majority of cases lead ultimately to results of economic importance.

It is obviously only right that any commercial advantages resulting from investigations carried out at the public cost should accrue to the State, and, if this principle were adopted, expenditure by the Government or geological research on the lines I have suggested would be sooner or later recouped by the mineral wealth rendered available to the community.

It is not, however, on terra firma alone that such investigations may be usefully carried out. The floors of the shallow seas that separate these Islands from one another and from the continent of Europe are still almost unknown from the geological standpoint, although their investigation would present no serious difficulties. Joly [1] has described an electrically driven apparatus which, when lowered so as to rest on a hard sea-floor, will cut out and detach a cylindrical core of rock, and retain it till raised to the surface. Subsequently he invented a still more ingenious device,[2] in which the force of the sea-water entering an empty vessel is substituted for electrical power, but unfortunately neither the one or the other has actually been tried or even constructed.

Meantime, however, vertical sections up to 80 cm. (2 ft. 7½ in.) of the mud of the deep seas have actually been obtained in iron tubes attached to sounding apparatus employed in the course of the voyage of the *Gaussberg*. These reveal a succession of deposits of which the lower usually indicate colder water conditions than the upper, and have been referred for that reason to the last Glacial Period.[3]

In many places rock fragments are dredged up by fishing boats. These should, of course, be used with caution in drawing conclusions as to the distribution of rocks *in situ* on the sea-bottom, as such fragments may have been transported when embedded in ice-sheets or in icebergs or other forms of floating ice, or entangled in the roots of floating trees; but where the rock-fragments can be shown to have a definite distribution, as in those described by Grenville Cole and Crook from the Atlantic to the West of Ireland,[4] and by Worth from the western portion of the English Channel,[5] they may be regarded as affording trustworthy information as to the geology of the area.

There seems every reason to believe that advances in submarine

[1] "On the Geological Investigation of Submarine Rocks": Sci. Proc. Roy. Dublin Soc., vol. viii, pp. 509–24, 189.

[2] "On the Investigation of the Deep Sea Deposits": ibid., vol. xiv, pp. 256–67, 1914.

[3] Philippi, *Die Grundproben der deutschen Südpolar Expedition*, 1901–3, vol. ii, pp. 416–17, 591–8.

[4] *On Rock-specimens dredged off the Coast of Ireland and their Bearing on Submarine Geology*, Mem. Geol. Surv. Ireland, pp. 1–35, Dublin, 1910.

[5] "The Dredgings of the Marine Biological Association" (1895–1906) as a contribution to the knowledge of the geology of the English Channel: Journ. Marine Biol. Assoc., vol. viii, pp. 118–88, 1908.

geology will not be of only scientific interest, but will bring material benefits with them. Even at present the working of coal-seams and metalliferous veins has been extended outwards beyond low-water mark, and, if evidence should be forthcoming that valuable deposits underlie the shallower waters of the North Sea at any point, there is no reason to doubt that mining engineers would find means of exploiting them. It seems quite possible that off the shores of Northumberland and Durham there are in addition to extensions of the neighbouring coalfield, Permian rocks containing deposits of common salt, calcium sulphate (gypsum and anhydrite), and, above all, potash salts comparable to those at Stassfurt, which have proved such a source of wealth to Germany.

No less important than the work of the Geological Survey is that of our great national museums. I have already alluded to the need for local collections to illustrate the geology of the areas in which they are situated. The museums of our larger cities and our universities will naturally contain collections of a more general character, but it is to our national museums that we must chiefly look for the provision of specimens to which those engaged in research can refer for comparison, and it is imperative that they should be maintained in the highest state of efficiency, if the best results are to be obtained from scientific investigations in this country. The ability and industry of the staff of the Mineral and Geological Departments of the Natural History Museum are everywhere recognized, as well as their readiness to assist all those who go to them for information, but in point of numbers they are undeniably insufficient to perform their primary task of examining, describing, arranging, and cataloguing their ever-increasing collections so as to enable scientific workers to refer to them under the most favourable conditions.[1] Even if the staff were doubled, its time would be fully occupied in carrying out these duties, quite apart from any special researches to which its members would naturally wish to devote themselves. The additional expense incurred by the urgently needed increase of the Museum establishment would be more than repaid to the country in the increased facilities afforded for research.

There is room, too, for a considerable extension in the scope of the activity and usefulness of our museums in other directions, and more especially in the provision of typical lithological collections illustrating the geology of different parts of the British Empire and of foreign countries.

So far as the United Kingdom is concerned, this requirement has been admirably fulfilled in the museums attached to the Survey Headquarters in London, Edinburgh, and Dublin, and there is a smaller collection of the same nature, excellent in its way, at the Natural History Museum. But to obtain a broad outlook it is essential that the attention of geological workers should not be confined to one country, however diversified its rocks may be, and

[1] Even the number of skilled mechanics is quite insufficient, though their work is urgently needed. In the Geological Department provision is only made for two, and at present but one is actually at work.

it is impossible to assimilate effectively publications dealing with the geology of other parts of the world without being able to refer to collections of the rocks, minerals, and fossils described.

The rocks, for instance, of the Dominion of South Africa are of the greatest scientific and economic interest, and many important communications have been published with regard to them. They present at the same time many features which distinguish them from European types, but I am not aware of any museum in this country where they are adequately illustrated.[1]

Such collections should include not only rock specimens in the ordinary sense of the term, but also examples of metalliferous veins and other mineral deposits which present important distinctive features.

In the Imperial Institute there are at the present time collections from most of the different constituent parts of the British Empire, which fulfil to a certain extent these requirements, and they have been employed by myself and others in demonstrations to the Geologists' Association in illustration of the geology of Peninsular India and different parts of Africa; but they are very incomplete, having been collected with the view of exhibiting, not so much the character of the rocks and mode of occurrence of the minerals, as the economic resources of the British Empire.

This is, of course, a function of the very greatest importance, but collections of minerals of intrinsic economic significance gathered together to assist in the development of the resources of the Empire should be organized on a different plan. They should be arranged, not according to the areas in which they occur, but with reference to the products obtained from them. The object of such collections is to enable those who are in want of materials for commercial purposes to ascertain where they can be obtained, and of what quality and at what price. For this purpose different samples of the same or similar ores or other products should be placed together irrespective of their origin, and each specimen should be accompanied by an assay or analysis, and such information with regard to its source and mode of occurrence as will enable the inquirer to form an opinion as to whether it will be likely to satisfy his requirements.

The lithological and palæontological collections which I am now advocating should, on the other hand, be arranged so that each group of specimens illustrates an area possessing distinctive geological features. Little has, hitherto, yet been done in this direction. The Mineral Department of the Natural History Museum possesses a large and extensive collection of foreign and colonial lithological specimens arranged according to localities, which is too little known, but it is naturally very unequal and incomplete, some countries being comparatively well represented and others scarcely at all. The Geological Department of the Museum is well provided with palæontological specimens, but these are arranged according to their biological affinities, and they might well be supplemented by

[1] [There is a very complete collection of the rocks of South Africa in the Sedgwick Museum, Cambridge.—Ed. Geol. Mag.]

a series of typical collections illustrating the fauna and flora of the more distinctive horizons in different areas. This is all the more important, as the mode of preservation may be very different in different places. It is probable that the geological surveys of British Dominions and Dependencies and of foreign countries would in many cases be able to supply such collections of rocks, mineral deposits, and fossils as I have suggested. Where this is not possible, the only practicable means of obtaining really typical collections is to despatch a representative of the Museum, preferably one of its own officers, to make one himself. The provision of such facilities for the study of the geology of other lands is especially desirable in London, in view of the number of students of mining and economic geology who receive their training in this country and ultimately go out into the world to find themselves face to face with problems in which a true understanding of the local geology is absolutely essential.

I shall not discuss here the important subjects of the indexing of geological literature and the preparation of abstracts of current publications. The former is already being efficiently dealt with by the Geological Society, and the latter will, I trust, be provided for in some way in the immediate future.

I now proceed to indicate some lines along which it seems to me probable that there are opportunities for progress in geological research.

In the investigation of the sedimentary rocks attention has been usually directed mainly to the larger and more obvious features, and these have sufficed to afford considerable insight into the conditions which prevailed when they were laid down. The detailed study of the minor structures or texture of these rocks by lens and microscope has, on the other hand, been comparatively neglected, though it is capable of affording us valuable information that could be obtained in no other way. There are, however, I need hardly say, important exceptions, the classical researches of Sorby extending over more than half a century, the investigations of Hutchings on the argillaceous rocks, and much useful work in recent years on the mineral constituents and microzoa of the sedimentary rocks generally. But, although individual sediments have been carefully studied, few, if any, attempts have been made to carry out a detailed examination of the successive beds of a stratigraphical succession comparable to the systematic zoning by means of fossils which has yielded such valuable results.

Not only ought the texture and composition of the individual laminæ to be patiently studied to obtain information as to the exact manner of their deposition, but attention should be more especially directed to the character of the transition by which one layer gives place to another, so as to determine, if possible, the cases where there has been a gradual passage without a break, and those in which there has been a pause in the deposition of greater or less duration, or even a removal of material, although nothing in the nature of an unconformity, however slight, can be detected. Even in apparently uniform deposits, such as Chalk and clay, variations in texture and composition may be brought out by special treatment and reveal

interesting details of the conditions under which they were deposited.

It is of special importance to recognize and examine in detail the occurrence of rhythmic repetitions of a similar succession of sedimentary materials and characters. A single cycle in such a succession may be only a twentieth of an inch in thickness, as in the case of ferruginous banding in the Lower Hangman Grits at Smith's Combe in the Quantocks, or may include 30 or 40 feet of strata, as in the Caithness Flags. Rhythms have been described from the pre-Cambrian of Finland, the Ordovician of North America,[1] the Permian of Stassfurt,[2] the Cretaceous of Arkansas,[3] and the Quaternary of Scandinavia and Palestine, and many more, no doubt, occur in the stratigraphical succession of different countries. It would probably be found that a similar repetition occurs in fine terrigenous deposits off the coast of tropical countries where there is a well-defined alteration of wet and dry seasons. In some places minor cycles may be superimposed on larger, as in the case of the Skerry Belts described by Bernard Smith[4] in the Upper Keuper of East Nottinghamshire. The general question of the significance of such rhythms of stratification must, however, be reserved for another occasion.

It is more difficult to arrive at the true interpretation of the phenomena presented by the endogenetic rocks[5] which have come into existence by the action of the forces of earth's interior, for the conditions of temperature and pressure under which they were formed, whether they are igneous rocks in the narrower sense, or mineral veins, or metamorphic in origin, were widely different from those with which we are familiar. Under such circumstances the ultimate physical principles are the same, but the so-called constants have to be determined afresh, and a new chemistry must be worked out. It is necessary, therefore, as far as possible, to reproduce the conditions that prevailed—a task which has been courageously undertaken and to a considerable extent accomplished by the Geophysical Laboratory of the Carnegie Institute at Washington.

By artificial means temperatures and pressures have been already produced far higher than those that were in all probability concerned in the evolution of any of the rocks that have been revealed to us at the surface by earth-movements and denudation, for it is unlikely that in any case they were formed at a greater depth than five or six miles, corresponding to a uniform (or, as it is sometimes termed, hydrostatic) pressure of 2,000 or 2,400 atmospheres, or at a greater temperature than 1,500° C. Indeed, it is probable that the vast majority of igneous and metamorphic rocks, as well as mineral veins, came into existence at considerably less depths and at more moderate temperatures. It is true that most of the rock-forming minerals crystallize from their own melts at temperatures between 1,100° C.

[1] Barrell, *Bull. Geol. Soc. Am.*, vol. xxviii, pp. 789–90, 1917.
[2] Ochsenius, *Zeitsch. für praktische Geologie*, vol. xiii, p. 168, 1905.
[3] Gilbert, *Journal of Geology*, vol. iii, pp. 121–7.
[4] GEOL. MAG., 1910, pp. 303–5.
[5] Crook, *Min. Mag.*, vol. xvii, p. 87, 1914.

and 1,550° C., but they separate out from the complex magmas from which our igneous rocks were formed at lower temperatures, rarely much exceeding 1,200° C., and frequently considerably less.[1]

It has been found possible at the Geophysical Laboratory to maintain a temperature of 1,000° C. or more under a uniform pressure of 2,000 atmospheres for so long a time as may be desired, and, what is equally important, the temperature and pressure attained can be determined with satisfactory accuracy, the temperature within 2° C., and the pressure within 5 atmospheres.

It has been ascertained that such uniform pressure as would ordinarily be present at the depths mentioned does not directly affect the physical properties of minerals to anything like the same extent as the difference between the temperature prevailing at the earth's surface and even the lowest temperature at which igneous rocks can have been formed. It has, however, a most important indirect action in maintaining the concentration in the magma of a considerable proportion of water and other volatile constituents[2] which have a far-reaching influence in lowering the temperature at which the rock-forming minerals crystallize out, in other words, the temperature at which the rock consolidates, and in diminishing the molecular and molar viscosity of the magma, thus facilitating the growth of larger crystals and the formation of a rock of coarser grain. They must also be of profound significance in determining the minerals that separate out, the order of their formation, and the processes of differentiation in magmas.

It is, therefore, obvious that any conclusions derived from the early experiments which were carried out with dry melts at normal pressures must be received with very considerable caution. Nor does much advance appear to have been made, even at the Geophysical Laboratory, in experiments with melts containing large amounts of volatile fluxes, and yet, if we are to reproduce even approximately natural conditions, it is absolutely necessary to work with magmas containing a proportion of these constituents, and especially water, equal in weight to at least one-third or one-half of the silica present. This will obviously present considerable difficulties, but there is no reason to doubt that it will be found possible to surmount them.

A much more formidable obstacle in realizing the conditions under which rocks are formed is the small scale on which our operations can be carried on. There are important problems connected with the differentiation of magmas, whether in a completely fluid or partly crystallized state, under the action of gravitation, for the solution of which it would seem for this reason impossible to reproduce the conditions under which nature works. Instead of a reservoir many hundreds of feet in depth, we must content ourselves in our laboratory experiments with a vertical range of only a few inches.

[1] It is probable that the temperatures recorded in some lavas higher than the melting-point of copper, which is well over 1,200° C., are due to chemical reactions, such as the oxidation of hydrogen, carbon monoxide, ferrous oxide, and perhaps sulphur. See Day & Shepherd, *Bull. Geol. Soc. Am.*, vol. xxiv, pp. 599–601, 1913.

[2] Johnston, *Journ. Franklin Inst.*, January, 1917, pp. 14–19.

There are, however, other phenomena that require investigation and that involve a great difference of level in their operation, but do not take place at such elevated temperatures. Such are some of the processes of ore deposition or transference, especially secondary enrichment. Here, with the friendly assistance of mining engineers, but at the cost of considerable expenditure, it might even be possible to experiment with columns several thousand feet in vertical height.

In any attempt to reproduce the processes of metamorphism other than those of a purely thermal or pneumatolytic character, or to imitate the conditions that give rise to primary foliation, we must consider the effects of non-uniform or differential pressure involving stresses that operate in definite directions and result in deformation of the material on which they act. Unlike uniform pressure which usually raises the crystallization point, differential pressure may lower it considerably and thus give rise to local fusion and subsequent recrystallization of the rock.[1] At the same time it profoundly modifies the structure, resulting in folds and fractures of every degree of magnitude. One of the most pressing problems of geology at the present moment is to determine the effects of non-uniform pressure in its operation at different temperatures, and in the presence of different amounts of uniform pressure, a factor which has probably an important influnce on the result, which must also depend on the proportion and nature of the volatile constituents which are present, as well as on the time during which the stresses are in operation. There seems no reason why valuable information should not be obtained on all those points by properly conducted experiments.

The time element in the constructive or transforming operations of nature cannot, of course, be adequately reproduced within the short space of individual human activity, or, it may be, that of our race; but I am inclined to think that, even in the case of metamorphic action, the importance of extremely prolonged action has been exaggerated.

In attempting to imitate the natural processes involved in the formation and alteration of rocks and mineral veins, we require some means of ascertaining when we have approximately reproduced the conditions which actually prevailed. It is not sufficient to bring about artificially the formation of a mineral occurring in the rocks or mineral deposits under investigation, for the same mineral can be reproduced in many ways. It is, however, probable that a mineral produced under different conditions is never identical in all its characters. Its habit, or the extent to which its possible faces are developed (a function of the surface tension), the characters of the faces which are present, its twinning, its internal structure, inclusions, and impurities, all vary in different occurrences, and the more closely these can be reproduced, the greater the assurance we obtain that an

[1] See Johnston & Adams, *Journ. Am. Chem. Soc.*, vol. xxxiv, p. 563, 1912; *Am. Journ. Sci.*, vol. xxxx, p. 206, 1913; Harker, *Proc. Geol. Soc.*, vol. lxxiv, pp. 75–7, 1919. It is interesting to note that similar principles apply to the pseudo-fluidity induced in clay by non-uniform pressure. See Crosthwaite, *Proc. Inst. C.E.*, December 19, 1916, p. 149; *Journ. and Trans. Soc. Eng.*, vol. x, pp. 82–6, 92–4; Ackermann, ib., pp. 37–80, 102–7.

artificial mineral has been formed under the same conditions as the natural product.

For this purpose it is above all necessary that there should be in the first place a systematic comparative study of these characters and of the association in which they are found. The results thus obtained should be of the greatest value in indicating the directions along which experimental work would be most probably successful. They should, of course, be supplemented by laboratory studies of the relations of such subsidiary crystallographic characters to the environment in the case of crystals which can be formed under normal conditions of temperature and pressure, and therefore under the immediate observation of the experimenter. Some work has, in fact, already been done on the effects on these characters of the presence of other substances in the same solution.

In the study of the secondary alterations of metalliferous deposits, especially those which consist of the enrichment of mineral veins by the action of circulating solutions, either of atmospheric or intra-telluric origin, the study of pseudomorphs gives, of course, valuable assistance in determining the nature of the chemical and physical changes that have taken place.

A successful solution of the problem of the exact conditions under which deposits of economic importance are found would be of incalculable value in facilitating their discovery and exploitation, and would be the means of saving a vast amount of unnecessary labour and expense.

The problem of the structure and nature of the earth's interior, inaccessible to us even by boring, would seem at first sight to be well-nigh insoluble, except as far as we can deduce from the dips and relations of the rocks at the surface their downward extension to considerable depths. We can, however, gain important information about the physical condition of the deeper portions from the reaction of the earth to the external forces to which it is subjected, and still more from a study of the "preliminary" earthquake tremors that traverse it, the time occupied in their passage, and the difference in intensity of those that follow different paths. These methods are, however, not applicable to the earth's crust. Its physical characters appear to be distinct from those of the interior, but very little is as yet definitely known about them, except of course in the neighbourhood of the surface, and for this reason they are usually ignored in calculating the paths of tremors traversing the earth. It seems to be separated from the deeper portions of the earth by a surface of discontinuity at which earthquake vibrations travelling upwards towards the surface may be reflected. Calculations based on the total time taken by these reflected waves to reach the surface after a second passage through the earth's interior appear to indicate that this surface of discontinuity, whatever its nature may be, is at a depth of about 20 miles, though there can be little doubt that this depth varies considerably from point to point.

The main earthquake vibrations appear to follow the curvature of the earth, and to be confined to its crust, instead of traversing the interior, as is the case with the preliminary tremors. In these

vibrations a period of about 17 or 18 seconds is usually predominant, and is believed to be due to the natural period of vibration of the earth's crust. Wiechert [1] assumes that there is a node half-way down and a free movement above and below, so that the full wave-length would be twice the thickness of the earth's crust. Assuming a velocity of propagation of 3½ km. per second, he calculates the depth of the crust to be approximately 30 km. There seems, however, to be no warrant for supposing that the lower surface of the crust is capable of free vibration. The fact that not only waves of compression but waves of distortion can traverse it shows that it must possess very high rigidity so far as forces of brief duration are concerned. The lower surface should therefore be regarded as a node, and only the upper as capable of free movement, so that the whole would correspond to a quarter of a wave-length. On the other hand, the velocity of 3½ km. per second, which is that of the propagation of waves round the earth's crust, in all probability a complex process, is not the same as the true velocity of vibrations passing upwards and downward through the earth's crust. Those with a period of about 18 seconds appear to consist partly of horizontal vibrations and partly of vertical; the former would seem to correspond to waves of distortion and the latter to waves of compression. The velocity of the former would probably be about 4 km. and the latter 7 km. per second, corresponding to the thicknesses of 18 km. and 31½ km. (11 and 20 miles). There is some evidence in the case of a distant earthquake of a period approximating to 30 km. per second, which would correspond, with waves of distortion, to a thickness of 30 km. (19 miles). However, in the present state of our knowledge of these vibrations such calculations are only of speculative interest.

There must be numerous surfaces of discontinuity in the earth's crust in addition to that forming its lower limit. Such would be the boundaries between great tracts of granite or granitoid gneiss and the basic rocks that in all probability everywhere underlie them; the surface dividing gneisses and crystalline schists from unmetamorphosed sediments overlying them unconformably; that between hard Palæozoic rocks and softer strata of later age; and the surfaces of massive limestones or sills. Wiechert observed at Göttingen, at the time of the Indian earthquake of April 4, 1905, small horizontal vibrations, superimposed on the others, with a period of only 1½ seconds. He believed that these were due to horizontal distortional vibrations of the local sandstone formation with a node at its basal surface. He found the velocity of similar vibrations at the surface to be 250 m. per second, and thence calculated the depth of the sandstone stratum to be 90 m.[2] No doubt similar correlations of terrestrial vibrations and the structure of the earth's crust may be made in other cases.

It deserves consideration, however, as to how far it may be possible to add to our knowledge of the earth's crust by experimental work with a view of the determination of surfaces of discontinuity

[1] *Göttinger Nachrichten*, 1907, pp. 468–9.

[2] Ibid., pp. 467–8.

by their action in reflecting vibrations from artificial explosions, a procedure similar to that by means of which the presence of vessels at a distance can be detected by the reflection of submarine sound waves. The ordinary seismographs are not suited for this purpose; the scale of their record, both of amplitude and of time, is too small for the minute and rapid vibrations which would be expected to reach an instrument situated several miles from an explosion, or to distinguish between direct vibrations and those that may arrive a second or two later after reflexion at a surface of discontinuity. As the cylinder on which the record is made would be only in motion while the experiment was in progress, there would be no difficulty in arranging for a much more rapid movement. At the same time it would be desirable to dispense with any arrangement for damping the swing of the pendulum, which would be unnecessary with small and rapid vibrations, and would tend to suppress them. It is possible that it might be better to employ a seismograph which records, like that devised by Galitzin shortly before his death, variations of pressure expressing terrestrial acceleration, instead of one which records directly the movements of the ground. It would, however, probably be found desirable to substitute for the piezo-electric record of pressure employed by Galitzin a record founded on the effect of pressure in varying the resistance in an electric circuit. This is, in fact, the principle of the microphone and most modern telephone receivers, but quantitatively they are very unreliable. This would not matter so much for the present purpose, where the time of transmission is the most important feature in the evidence, but satisfactory results even in this respect appear to be given by Brown's liquid microphone, from which the record could be taken, if desired, by means of the reflection of a mirror, attached to the needle of the galvanometer.

Evidence of the structure of the earth's crust is also afforded by observations on the direction and magnitude of gravitation, which have been carried out in considerable detail in India and the United States—especially in the neighbourhood of great mountain ranges. At the present time the problem of correlating the variations observed with the underground structure is only in an embryonic stage. It is probable that our greatest hope of advancing researches with this object is by detailed work in areas which present no marked orographical features, and where the geological structure is already fairly well ascertained.

The same remarks apply to the results obtained by magnetic surveys. Apart from the marked effect of masses of magnetite in the immediate neighbourhood of the surface, local magnetic irregularities appear to be mainly determined by the presence of basic igneous rocks,[1] but there seems to be considerable room for research as to the relation between these phenomena and the form and composition of an igneous intrusion.

In this review of some of the possibilities of geological research I cannot claim to have done more than touch the fringe of the

[1] Cox, Abstracts of the Proceedings of the Geological Society of London, 1918, pp. 71–4.

subject. In every direction there is room for the development of fresh lines of investigation, as well as for renewed activity along paths already trodden. Whether my particular suggestions prove fruitful or not, they will have served their purpose if they have stimulated anyone to look for new fields of work.

Postscript.—Since this address was written, I have learnt that Professor Kendall has from time to time made valuable suggestions with regard to the association of the Survey with local workers, more especially the geological staff and students of our colleges.

REVIEWS.

I.—Shore Processes and Shoreline Development. By Douglas Wilson Johnson. 8vo; pp. xvii + 584, with 73 plates and 149 text-figures. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Ltd., 1919. Price 23*s.* net.

WHILE this book was in preparation Mr. Johnson was Associate Professor of Physiography in Columbia University. When he wrote the preface he was on his way to France, and he claims the indulgence of the reader for the lack of the final supervision which he had hoped to give the proofs. But it is only in details that indulgence is needed; in essentials the book seems to have suffered little from the circumstances under which it was produced.

It is the best and most complete exposition of its subject that has yet appeared. The style is lucid, though at times unnecessarily diffuse; the work of previous writers is discussed, with copious references to the original papers, but the author retains his own independent judgment, which is always thoughtful and never dogmatic. Even where the reader disagrees he will recognize that the author is making an honest attempt to discover the truth and is not endeavouring to enforce a preconceived opinion.

The general scheme of the work is clear and logical. The first three chapters deal with waves and currents, these being the chief agents, apart from changes of level, that tend to alter the shape and character of coasts. Questions of terminology and classification are next discussed, and having thus cleared the ground the author proceeds to consider the development of the shore, a subject which occupies nearly half the volume. In his treatment he separates the "shore profile", or the shape of the shore in section, from the "shoreline", the shape of its outer boundary in plan. Finally, there are two chapters on special features, such as beach ridges, ripple-marks, etc.

In the chapters on waves no attempt is made at a mathematical analysis of wave-motion, which would indeed be out of place in a work of this nature; but there is a summary of the results obtained by such analysis. On the vexed question of the depth at which wave-action is perceptible the author adopts the widely held opinion that 600 feet may be taken as the limit for ordinary wave-disturbances, though occasionally effective motion may descend beyond that depth.

In the section on terminology the author tries to avoid, as far as he can, the introduction of new terms; and by restricting the significance of common English words he hopes to make them serve his purpose. For him the "coast" is the sea-cliff and a zone of indeterminate width on its landward side; the "shore" is the belt between low-water mark and the cliff; "beach" is the actual material which moves along the shore, or on and off the shore. In his choice of words the author endeavours to do as little violence to the language as possible; but artificially to restrict the meaning of such widely used expressions may easily lead to misunderstanding. Indeed, because no vaguely limited term is left, the author himself is sometimes compelled to use one or other of these words in a wider sense than is contemplated by his own definition. The chapter on the development of the shore profile, for example, deals not only with the shore but with the whole width from the cliff to the edge of the continental shelf.

The classification of shores that the author follows is the simple and natural one into (1) shorelines of submergence, (2) shorelines of emergence, (3) neutral shorelines, which do not owe their characteristic features either to submergence or emergence, (4) compound shorelines, the essential features of which combine elements of at least two of the foregoing classes.

The account of the development of the shore profile suffers from the defect that it is almost exclusively deductive, and illustrative examples are too few. From a consideration of the agencies concerned in its production the author deduces the forms that the ideal profile should pass through; but whether real profiles assume these forms he makes little attempt to prove. The truth is that accurate profiles are not readily obtained. Even the large-scale maps of a Government Survey are not sufficiently minute with regard to altitudes on the land or depths in the sea, and in most cases a special survey would be needed. In consequence of this our knowledge of real profiles is far less complete than our knowledge of real shorelines.

It is no doubt for this reason that the chapters on the development of the shoreline are not open to the same criticism. Deduction is employed as freely, but there are frequent comparisons with actual examples. Probably this is the section of the book that will be found most generally attractive.

It would take too much space to follow the author further. The English geologist will be interested in the account of Dungeness; perhaps he may not be sorry to find that Chesil Bank is only incidentally referred to. The "falls" of Orford Ness deserve more attention than they have received, either in this book or elsewhere.

An important general conclusion arrived at by the author is that marine denudation is more effective, compared with fluvial denudation, than the older school of geologists have usually been disposed to allow.

Illustrations, both in the text and in the form of plates, are numerous and, for the most part, good; but, except in a few instances, the maps are without a scale. This is the most serious of the omissions that call for the indulgence which the author claims.

A valuable feature of the book is the fullness of the references to previous literature, which appear at the end of each chapter, and again, in alphabetical list, at the end of the volume.

P. L.

II.—On the Inclination of the Thrust-plane or Reversed Fault between the Siwalik and Murree Line of Formations near Kotli, Jammu Province. By C. S. Middlemiss. Rec. Geol. Surv. India, vol. l, pp. 122–5, pl. xxviii, 1919.

In the Geological Magazine for 1903 (pp. 305–6) Mr. Lake published a very short paper on "The Circular Form of Mountain Chains". In this paper Mr. Lake showed that if Suess' conception of mountain chains as the crumpled edges of flat-based earth-scales is true their intersection with the surface must always be an arc of a circle; furthermore, he pointed out that the angle which a plane makes at its outcrop with the surface of the sphere is equal to the angular distance measured on the surface of the sphere between the centre and circumference of the circle formed by the outcrop of the plane. Mr. Lake went on to say, "If I were to attempt, on this view, an ideal representation of the Himalayas, I should draw, some little distance below Middlemiss' Section VI" (referring to a paper in Mem. Geol. Surv. India, vol. xxiv, pt. ii), "a thrust-plane making an angle of 14° with the horizontal."

It has hitherto been customary in drawing ideal sections of the Himalayas to represent fold-faults of this category as having steep inclinations, usually something between 45° and 60° with the horizontal, and Mr. R. D. Oldham even speaks of the main boundary fault as being "a nearly vertical plane of separation" (Mem. Geol. Surv. India, vol. xlii, pt. ii, p. 4).

As described in the paper quoted at the head of this review, Mr. Middlemiss has plotted with great care on the new contoured 1 in. map of Jammu and Kashmir the plane of division between the younger zone of Siwalik rocks and the older Murree zone below. This plane can be traced with great accuracy owing to the strong colour-contrast between the two series. The course of the fault when thus plotted, as shown on the map accompanying the paper, makes two very distinct V-shaped upstream bends, and by using the data thus afforded Mr. Middlemiss has calculated that the actual angle of dip of the plane is from 12° to 15° with the horizontal. This affords a remarkable confirmation of the soundness of Mr. Lake's reasoning and is a valuable instance of the untrustworthiness of inferences drawn from field-observation without accurate mapping to scale.

III.—The Magnesite Deposits of Bulong. By F. R. Feldtmann. Bull. 82, Geol. Survey Western Australia. pp. 38, with 2 plates and 7 figures. Perth, 1919.

This Bulletin gives the results of a recent exploration, stimulated by war conditions, of deposits of magnesite in the North-East Coolgardie Goldfield, together with a general account of the

occurrences of magnesite in other countries and its uses. The Bulong district lies in a complex of basic and ultrabasic greenstones, the most prominent members of which are serpentines and amphibolized gabbros, apparently local differentiations of a highly basic magma, intruded as one mass. These are traversed by a number of porphyrite dykes and are in contact with an area of sheared sediments, including slates and pebble beds. The magnesite occurs for the most part as irregular veins in the serpentine and is doubtless formed by the ordinary alteration-processes of that rock. It is comparatively free from lime, but contains moderate amounts of silica and iron. The amount of the mineral present is now wholly uncertain owing to the irregular nature of the deposit and the thick detrital covering, but it appears to be very large, and ranges in quality to 90 or even 95 per cent $MgCO_3$.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

November 5, 1919.—Mr. G. W. Lamplugh, F.R.S., President, in the Chair.

A lecture was delivered by Hugh Hamshaw Thomas, M.A., F.G.S., "On some Features in the Topography and Geological History of Palestine," illustrated by aeroplane photographs taken during the War.

The lecturer observed that a perfectly new method of illustrating and investigating some branches of physical geology is afforded by aeroplane photography. It seems firstly to illustrate in a very striking and convincing form many geological phenomena, such as the structure of a volcano or the land-forms resulting from erosion, and may be of value in the teaching of the science. In the second place it may, in certain circumstances, become a valuable means of research, especially in connexion with river-development or denudation in a region which is somewhat inaccessible, or where the surface of the ground is very complicated and the main features are obscured by a mass of less important detail. The lecture dealt principally with the illustration of the physical features of Palestine, and owed its origin to the systematic photo survey made over Central Palestine during the War. The photographs were originally taken for the purpose of constructing detailed maps, and the examples shown had been selected from a large mass of similar material which still exists in the form of negatives, and these may eventually become available in this country for further study and research. The demarcation of the coastal plain from the foot-hills of the upland country is often well shown by oblique air-photographs, and the weathering-out of the flat alluvial ground by the winter rains to give characteristic wadis is clearly seen. In the central hill-country the terraced hills show the relation of the scenery to the underlying rock, but their general sculpture is regarded as belonging to a former period of great precipitation. In arid

country, where the underlying rock is laid bare, the aeroplane camera often shows the general geological structure of the district.

The lacustrine deposits of the Jordan Valley and their weathering was shown, and also the form of the drainage-channels running down into the main valley. The depression of the Dead Sea with reference to the surrounding country has resulted in cañon formation in many places. Some evidences of faulting at different periods can be distinguished.

The Jordan at present forms an interesting study in river-development, and many of its main features were demonstrated. The relation of the Jordan to the Orontes has been considered, and an aeroplane photographic survey of the country between the two rivers indicates that the Jordan probably originated in Northern Syria in earlier times. The Syrian portion of the stream has been captured by the younger Orontes, and this has had a very important effect on the whole topography of the Jordan Valley.

A further study of the aeroplane photographs already taken, and of the maps made from them, may throw much new light on the questions of climatic changes and of topographical changes due to faulting in Palestine.

II.—Mineralogical Society.

Anniversary Meeting, *November* 4.—Sir William P. Beale, Bart., K.C., President, in the Chair.

Dr. W. R. Schoeller and A. R. Powell: "Villamaninite, a new mineral." The new mineral, which occurs, disseminated in black grains and plates, with a distinct cleavage, and in small nodules, with a radially fibrous structure, in a crystalline dolomite, near Villamanin, Cármenes district, León province, Spain, has probably a composition corresponding to (Cu, Ni, Co, Fe) (S, Se)$_2$. Its streak is sooty black, hardness 4·5, and specific gravity 4·4–4·5; it is opaque.

Arthur Russell: "On the Occurrence of Phenakite and Scheelite at Wheal Cock, St. Just, Cornwall." The author found good specimens of these minerals in 1914 at Wheal Cock, which is the locality whence came the crystal (undoubtedly phenakite) described by Sowerby in 1804 as argilla electrica or white tourmaline; phenakite was not known till 1833 as a distinct species.

L. J. Spencer: "New Crystal-forms on Pyrites, Calcite, and Epidote." On pyrites the dyakis-dodecahedron (641) occurs as large, well-developed faces on five specimens, one of them from Traversella, Piedmont, and the others from coal shales of unknown locality. On 424 crystallized specimens of pyrites in the British Museum collection 35 crystal-forms were noted. Faces of the cube are present on 76·6 per cent of the specimens, the octahedron on 62·7 per cent, the pentagonal dodecahedron (210) on 54·7 per cent, and the dyakis-dodecahedron (321) on 36·1 per cent. As simple forms, not in combination with other forms, they are represented by 12·2, 2·5, and 0·5 per cent respectively. The decomposition of

specimens of pyrites in collections was discussed. Calcite, a clear scalenohedral crystal, probably from Iceland, consists of a combination of the two scalenohedra $(20\bar{1})$ and $(12.0.\bar{7})$, both largely developed, and with an angle of $4\frac{1}{2}$ degrees between corresponding faces. Epidote, a crystal, probably from Ala, Piedmont, closely resembling in appearance the yellow prismatic crystals of anatase, carries a minute face (134) (Dana's orientation) in addition to twenty other crystal-forms.

Dr. G. F. Herbert Smith: "A Curious Crystal from the Binnental." The crystal, which was found with a few loose sartorite crystals in the Trechmann Collection, is twinned and tabular in habit, and shows signs of corrosion. The symmetry is peculiar, since, although a face occurs at right angles to the prism edge, it is neither a plane nor a pole of symmetry, and the crystal appears to represent a new species of sulpharsenite.

CORRESPONDENCE.

THE TERTIARY GEOLOGY OF DEVON AND CORNWALL.

Sir,—Referring to your reviewer's remarks in the November number, p. 521, on an inquiry into the recent views relative to "The Tertiary Geology of Devon and Cornwall", may I be allowed a few lines to meet the objections that the "argument concerning the age of the limestone caverns is not very clear, and its bearing on the point at issue is not obvious".

The point at issue is the submergence of the peninsula during the Pliocene era as predicated by the platform theory. Of the seven standpoints from which the theory was considered, the caverns were taken as one contributing important controverting evidence. It was shown that caverns are almost entirely formed by solution of the rock, an immeasurably slow process, requiring geological ages to form these large subterranean hollows. It was also pointed out that the lowest deposits in the Devon caverns are glacial formations (surface material swept through the swallow-holes into the lowest depths during extraordinary climatic conditions) that determine the pre-Glacial existence of the cavern. It follows that the human and animal relics found in this deposit (the breccia) must have been of Pliocene origin. Now as the elevation of the caverns above the sea-level during their whole existence is unquestioned, and when the many ages taken in the formation of the similar Derby and Yorkshire caverns are put in comparison, it does not appear consistent with the character of the facts to assign the formation of the Devon caverns to the comparatively short geological period that must be implied to terminate the Pliocene era, as subsequent to the vast space of time drawn upon that era, which the enormous results embraced by the platform theory demand.

I submit the cavern phase of the argument to be one that is relevant, cogent, and obvious.

H. J. Lowe.

Torquay.

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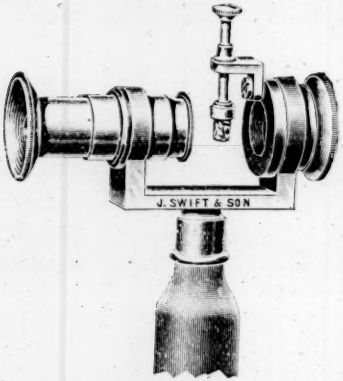

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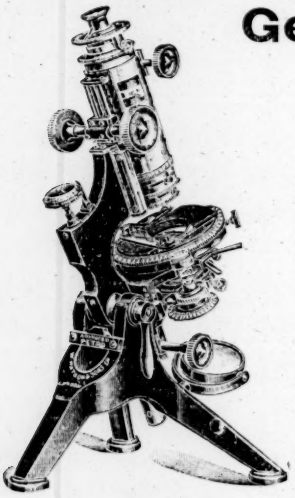

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